CHAPTER 4

POWER DISTRIBUTION

A power distribution system includes all parts of an electrical system between the power source and the customer's service entrance. It includes the use of overhead and underground transmission methods and the equipment required for the control and protection of the system and personal. The power source may be either a local generating plant or a high-voltage transmission line feeding a substation that reduces the high voltage to a voltage suitable for local distribution. At most advanced bases the source of power will be generators connected directly to the load.

This chapter will be mainly concerned with the overhead distribution system. Generally speaking, an overhead distribution system can usually be installed and maintained more efficiently than an underground system. Also, for equivalent conductor size, an overhead system has higher current capacity and offers greater flexibility with regard to changes.

In this chapter you will learn about line work safety, pole climbing, and the tools and equipment a lineman uses. You will learn the basics in constructing and maintaining a power distribution system as well as the component parts of the system.

SAFETY IN POWER DISTRIBUTION

The topic of safety that is covered in this chapter is the most important. The potential for an accident is constantly present during construction and maintenance operations but is much greater when crew members are working on power distribution systems.

The presence of HIGH VOLTAGE in your work area increases your need for heightened awareness of the potential for serious injury or death that may be caused by carelessness and the necessity to take precautions to ensure the safety of all personnel.

EQUIPMENT REQUIREMENTS

Cranes, earth augers, bucket trucks, and line trucks with booms that are capable of contacting HIGH-VOLTAGE lines because of their height capabilities must be operated with caution. A minimum separation of 10 feet must be maintained between the equipment and the energized power circuits at all times. The equipment must be maintained in first-class mechanical condition. **SAFETY FIRST** must be the primary goal.

PERSONNEL SAFETY

To ensure the SAFETY of all personnel working on power distribution lines, you should observe the following safety precautions:

- Ensure that all hot-line equipment is routinely tested according to the manufacturer's specifications before use.
- Ensure that all hot-line equipment, including rubber gloves, is stored in appropriate containers to provide the required physical protection.
- Perform air leak tests on rubber gloves before each use.
- Never use rubber gloves without the leather outer protectors.
- Ensure that the hard hats of crew members are rated to withstand 20,000 Vac and that no metal devices are or have been attached to them.
- All members of the line crew must be trained in the application of the first-aid techniques required to treat victims of electrical shock.
- Ensure that no individual is ever allowed to work alone or near circuits or devices conducting electrical energy over 30 Vac.
- Tag and lock out all circuits that are de-energized to perform work.
- Install ground sets between the electrical source and your work on all de-energized circuits when the disconnecting means is not in sight or when the potential for contact between the de-energized circuit and an energized circuit is present.
- Maintain a minimum of 3-foot clearance between personnel and any live power circuit or device conducting between 600 and 20,000 Vac. Higher

voltages require an increased separation of personnel and energized circuits.

Many other safety procedures are required on the job—too many to list here. *The Lineman's and Cableman's Handbook*, the *Electrical Transmission and Distibution Safety Manual,* NAVFAC P-1060, and Occupational Safety and Health Administration instructions are a few references you need to read to learn more about job safety.

POWER LINE COMPONENTS

Power line components are the different items used to construct a power distribution line. The basic components of a power line are poles, guys, crossarms, insulators, and conductors.

POLES

The three types of poles used most frequently in pole-line construction are wood, concrete, and steel. You will find all three types of poles in the field, but most of your work will be with the wooden type.

All wooden poles used for line work are chemically treated to resist damage caused by insects and rotting. Many of the older poles now in use were treated with creosote. Most new poles are treated with less toxic chemicals and are therefore safer to work with.

WARNING

Creosote is a toxic compound that irritates the skin and sometimes causes blistering. You should use extra care when working around poles treated with creosote to prevent contact between these poles and the bare skin.

The supply of wood poles available for use in constructing electric power lines has decreased in recent years. Substitute materials, such as concrete, aluminum, fiber glass and laminated and composite wood poles, are now being used.

The classification of wooden poles is determined by the length, circumference at the top, and circumference measured 6 feet from the butt end. Pole sizes begin at 20 feet and are increased in 5-foot increments up to 90 feet in length. Pole-top circumference increases 2 inches for every class from Class 7 to Class 1. The Navy, however, does not normally order poles smaller than Class 5.

American National Standard, ANSI 05.1, entitled "Specifications and Dimensions for Wood Poles" provides technical data for wood utility poles.

POLE GUYS

When constructing power lines, you will need a means of strengthening poles and keeping them in position. To accomplish this, you can use guys, anchors, and braces. Anchors are buried in the ground, and guy wires are connected to the anchors and attached to the pole, or a push brace may be used. The guys and braces are used to counter the horizontal strain on the pole caused by conductors, pole-line components, and abnormal loads, such as snow, sleet, or wind.

Anchors

Anchors are designed to meet specific soil conditions. You must know the type of soil before you can select a certain type of anchor. Anchors come in many forms and have different methods of installation. Figure 4-1 shows the most common types of anchors. The expanding anchor, the most popular type, as shown in figure 4-1, view A, is designed to be placed in the ground and then expanded with the aid of the tamping bar. Once expanded, the anchor is secure and strong enough to secure the guy. Figure 4-1, view B, shows a plate of a never-creep anchor, and view C shows a screw anchor that is installed using an earth auger. These three types of anchors are manufactured and are commonly used because of their ease of installation.

Another type of anchor that is shown in figure 4-1, view D, is called a deadman. This anchor is made of a 6- to 8-foot-long piece of treated power pole and an anchor rod. It is installed 6 feet deep in loose or sandy type of soil, with an angle of pull for the guy wire and rod assembly equal to 45 degrees. The deadman is not widely used today because of the time and effort required to place it.

Anchor Rods

The anchor rod serves as the connecting link between the anchor and the guy cable. The rod must

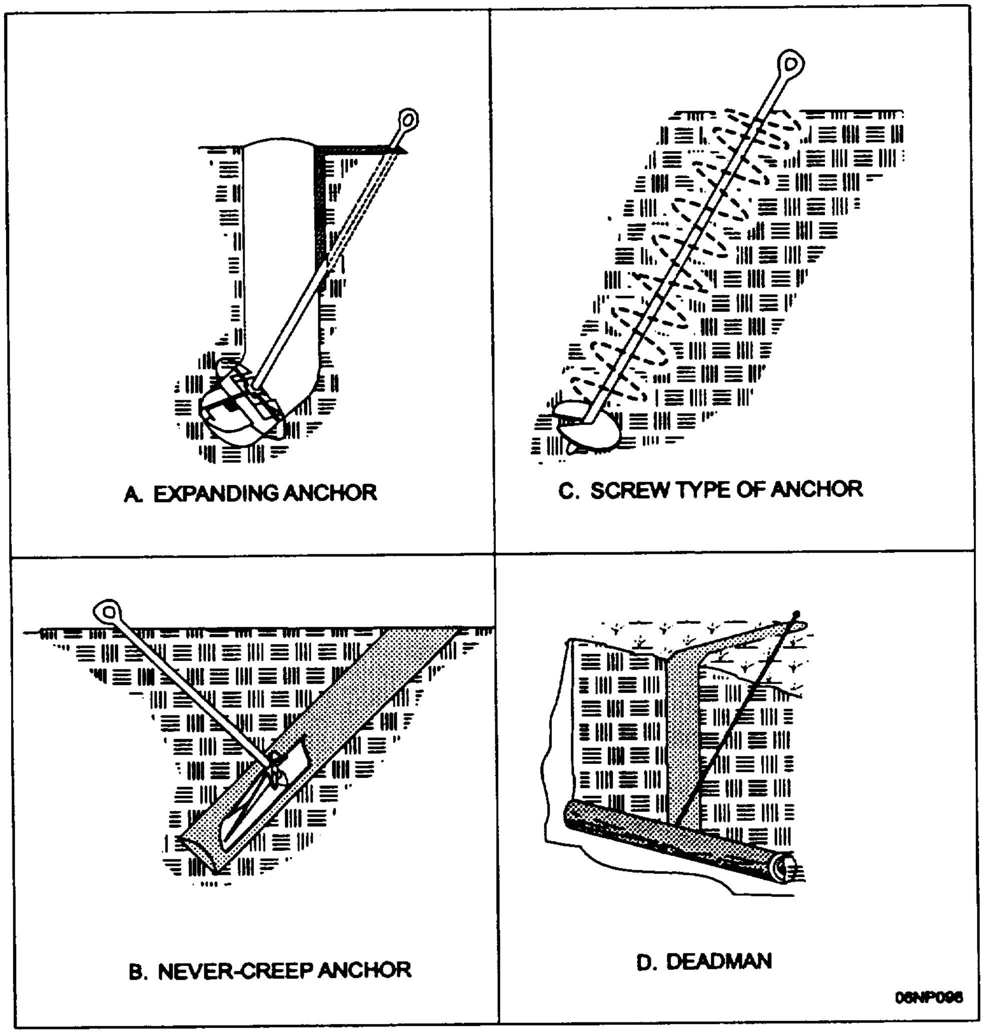


Figure 4-1.—Anchors.

have an ultimate strength equal to, or greater than, that required by the down-guy assembly. Anchor rods vary in diameter from 1/2 to 1 1/4 inches and in length from 3 1/2 to 12 feet.

Guy Wire

The wire, or cable, normally used in a down guy is seven-stranded galvanized steel wire or seven-stranded alumoweld wire. Alumoweld wire consists of steel wire strands coated with a layer of aluminum to prevent corrosion. Guy wire is used in various sizes with diameters from 1/8 to 1 3/4 inches.

Guys

A guy is a brace or cable fastened to the pole to strengthen it and keep it in position. Guys are used whenever the wires tend to pull the pole out of its normal position and to sustain the line during the abnormal loads caused by sleet, wind, and cold. Guys counteract the unbalanced force imposed on the poles by dead-ending conductors; by changing conductor size, types, and tensions; or by angles in the transmission or distribution line. The guy should be considered as counteracting the horizontal component of the force with the pole or supporting structure as a strut resisting the vertical component of the forces.

DOWN GUY.—A "down guy" consists of a wire running from the attachment near the top of the pole to

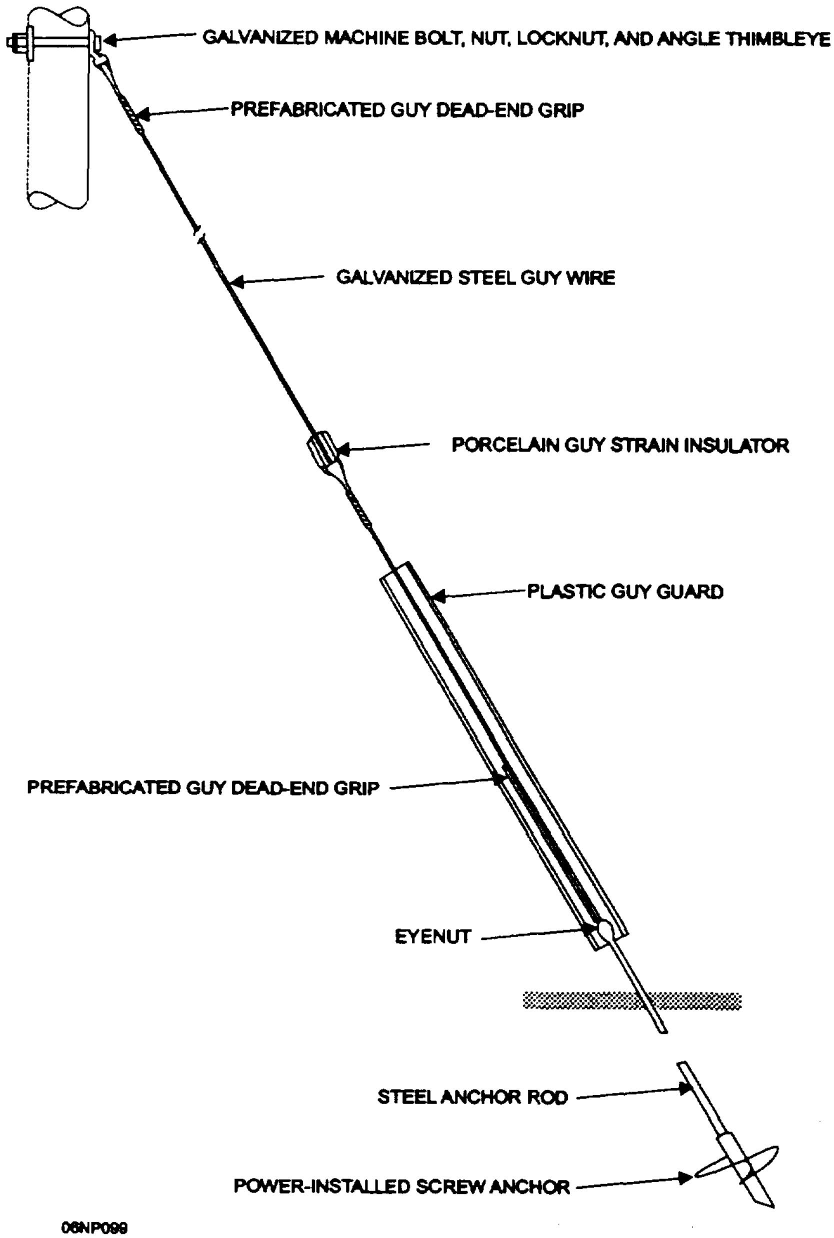


Figure 4-2.—Down-guy assembly.

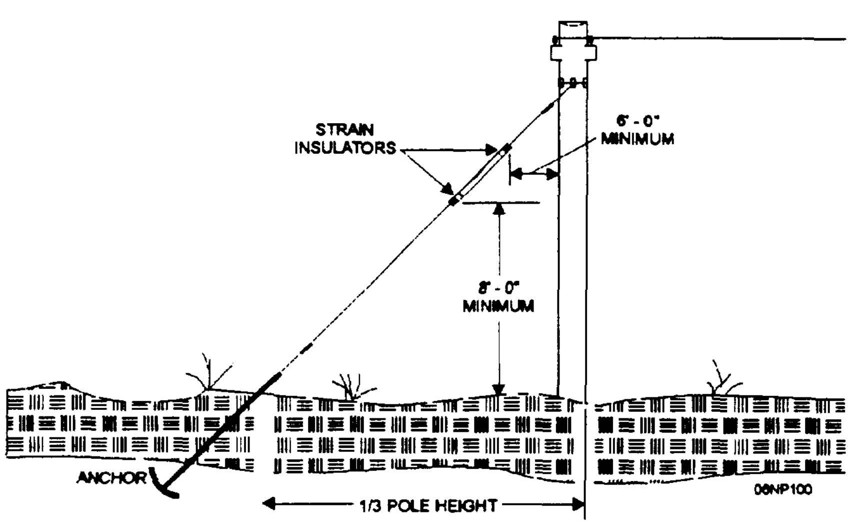


Figure 4-3.—Dead-end guy.

the rod and anchor installed in the ground (fig. 4-2). This type of guy is preferable if field conditions permit its installation since it transfers the unbalanced force on a pole or structure to the earth without intermediate supports.

A down guy used at the ends of pole lines to counterbalance the pull of the line conductors is called a "terminal guy" or a "dead-end guy" (fig. 4-3). All corners in the line are considered as dead ends. They should be guyed the same as terminal poles, except that there will be two guys, one for the pull of the conductor in each direction (fig. 4-4).

SIDE GUY.—When the line makes an angle, a side pull is produced on the pole. Side guys should be installed to balance the side pull (fig. 4-5). When a branch line takes off from the main line, an unbalanced side pull is produced. A side guy should be placed on the pole directly opposite to the pull of the branch line.

STORM GUY.—Guys are installed at regular intervals in transmission lines that extend long distances in one direction to protect the line from excessive damage as a result of broken conductors. Guys installed to protect the facilities and limit the damage if a conductor breaks are called "line guys" or "storm guys" (fig. 4-6).

SIDEWALK GUY.—An anchor guy with a horizontal strut at a height above the sidewalk to clear the pedestrians on the sidewalk is referred to as a "sidewalk guy" (fig. 4-7).

SPAN GUY.—A span, or overhead, guy consists of a guy wire installed from the top of a pole to the top of an adjacent pole to remove the strain from the line conductors. The span, or overhead, guy transfers the strain on a pole to another structure. This may be to another line pole or to a stub pole on which there is no energizer equipment. A span guy is always installed to

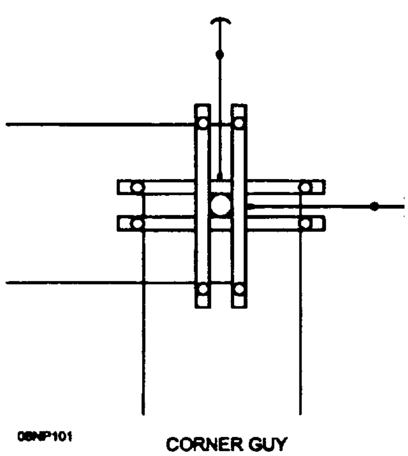


Figure 4-4.—Corner guy.

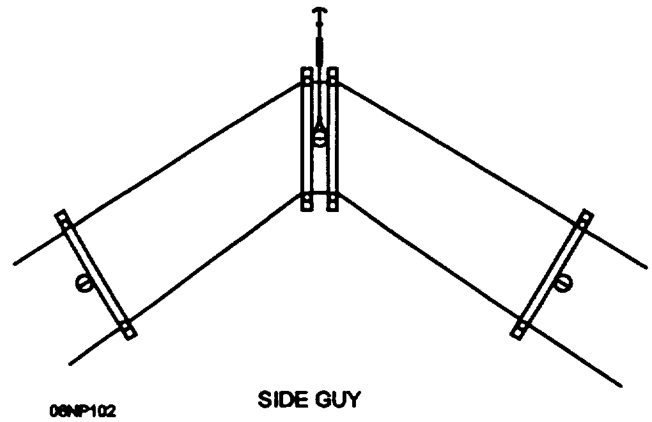


Figure 4-5.—Side guy.

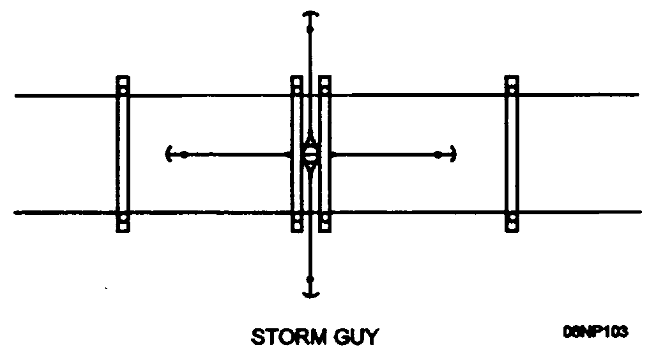


Figure 4-6.—Storm guy.

extend from the strain pole to the same or lower level on the next line pole.

HEAD GUY.—A guy wire running from the top of a pole to a point below the top of the adjacent pole is

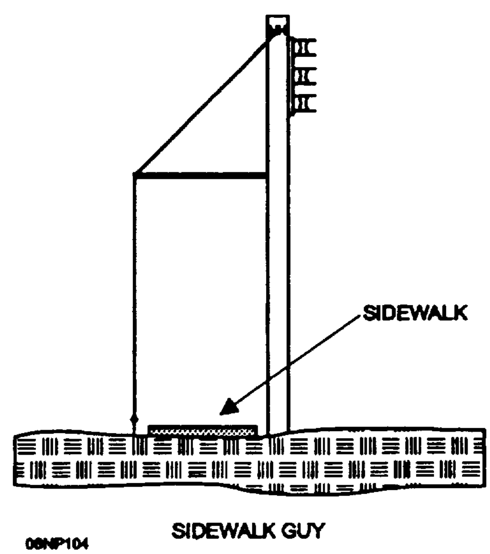


Figure 4-7.—Sidewalk guy.

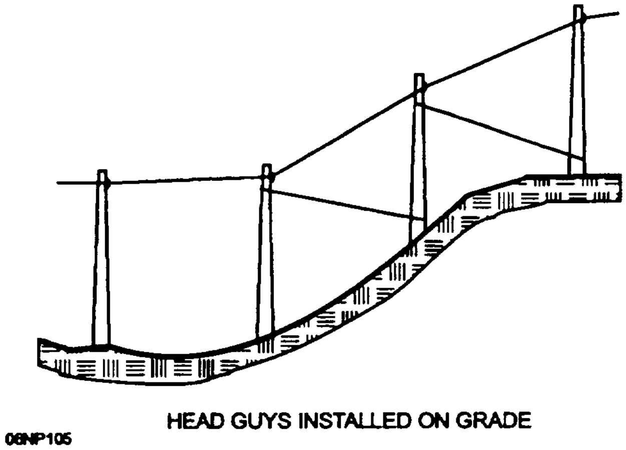


Figure 4-8.—Head guy.

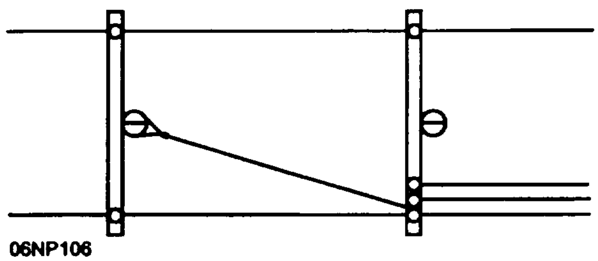


Figure 4-9.—Arm guy.

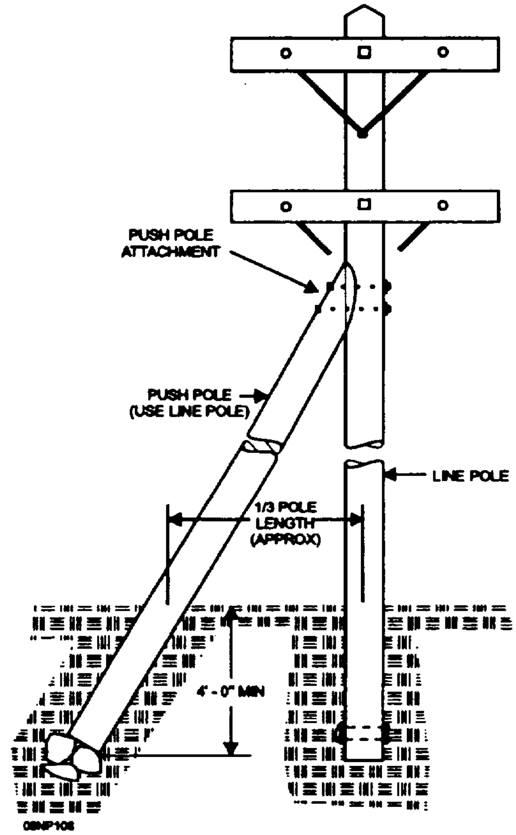


Figure 4-11 .-Push guy.

called a "head guy" (fig. 4-8). Lines on steep hills are normally constructed with head guys to counteract the downhill strain of the line.

ARM GUY.—A guy wire running from one side of a crossarm to the next pole is called an "arm guy." Arm guys are used to counteract the forces on crossarms that have more wires dead-ended on one side than on the other (fig. 4-9).

STUB GUY.—A guy wire installed between a line pole and a stub pole on which there is no energized equipment is called a "stub guy" (fig. 4-10). A down guy is used to secure the stub pole. This type of guy is often installed to obtain adequate clearance for guy wires extending across streets or highways.

PUSH GUY.—A push guy, or a push brace, is used when it is impossible to use down guys (fig. 4-11). When it is impossible to obtain sufficient right-of-way for a pole guy, the push brace can usually be installed. The push guy is constructed from an old power pole and a special bracket called a push brace attachment.

CROSSARMS

A crossarm is a specially treated wooden member that is secured to a pole and used to mount various types

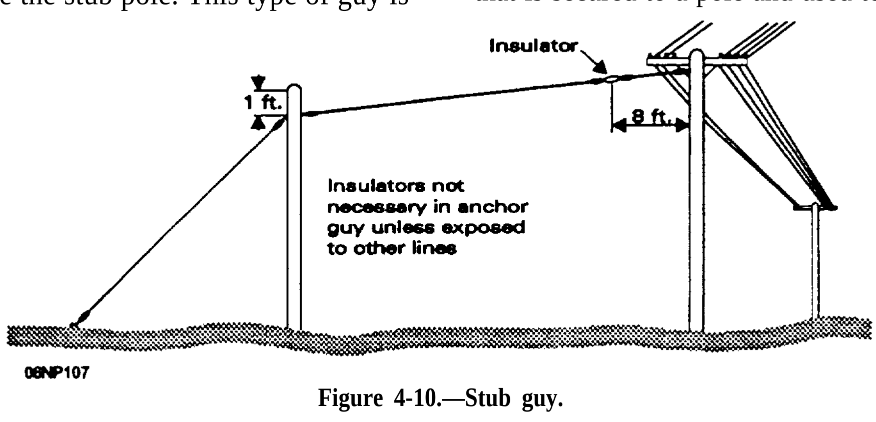


Figure 4-10.—Stub guy.

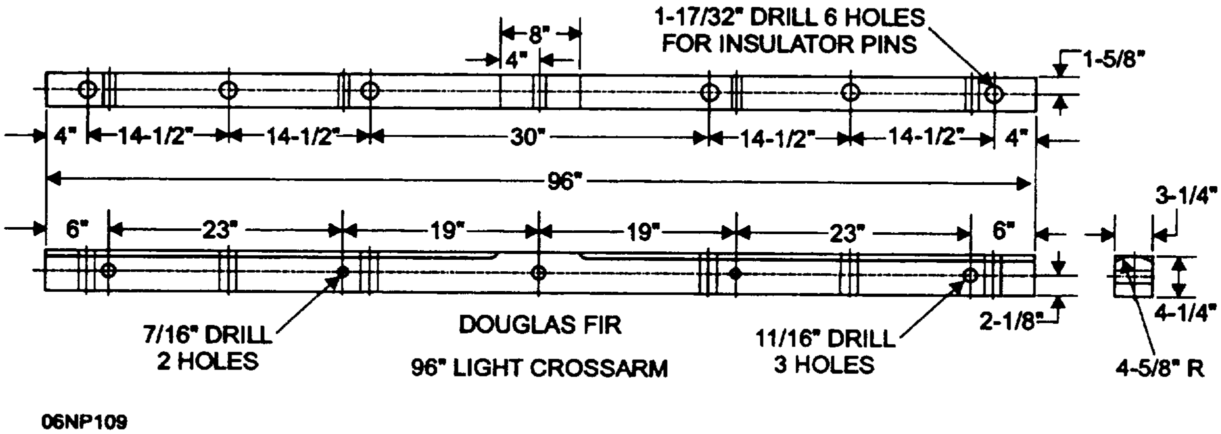


Figure 4-12.—Crossarm.

of circuit protection devices and to support the conductors. The crossarms used in power distribution come in three common sizes; namely, 3 1/4 inches by 4 1/4 inches, 3 1/2 inches by 4 1/2 inches, and 3 3/4 inches by 4 3/4 inches. The spacing for insulators on the crossarms, as shown in figure 4-12, meets the minimum standards for conductors at all distribution voltages used by the Navy. In your naval service you may come across larger wooden crossarms or crossarms made of steel. These crossarms are designed to support increased strain or to use with transmission lines carrying higher voltages.

SINGLE ARMS

Single arms are used on straight lines when no excessive strain needs to be provided (fig. 4-13). When crossarms are installed, every other crossarm faces in the same direction.

DOUBLE ARMS

A double arm should be used at line terminals, at corners, at angles, or at other points when there is an excessive strain (fig. 4-14). When lines cross telephone circuits or railroad crossings, double arms also should be used, as more than ordinary safety is required at such points. When two or more transformers are mounted on the same pole, double arms, as a rule, are used for their support.

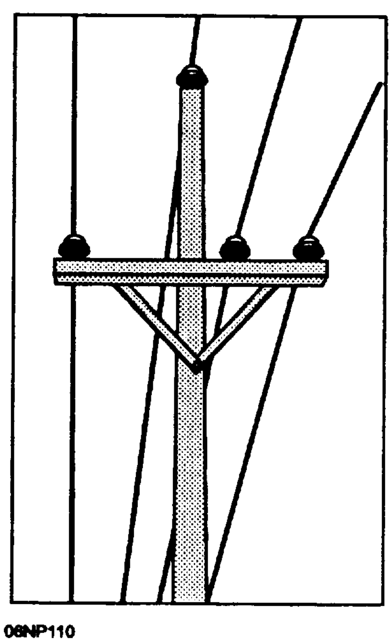


Figure 4-13.—Single-arm construction.

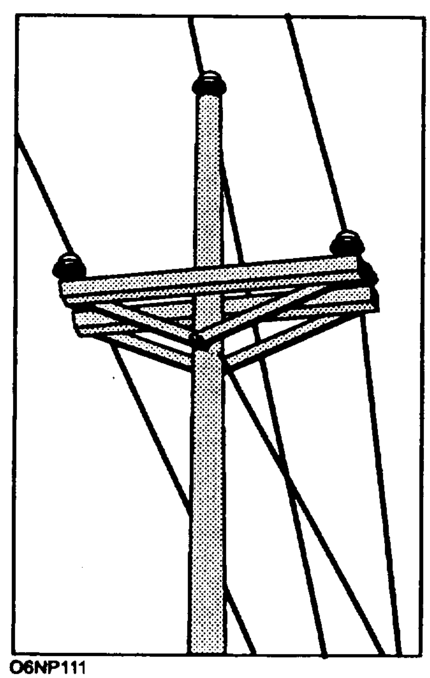


Figure 4-14.—Double-arm construction.

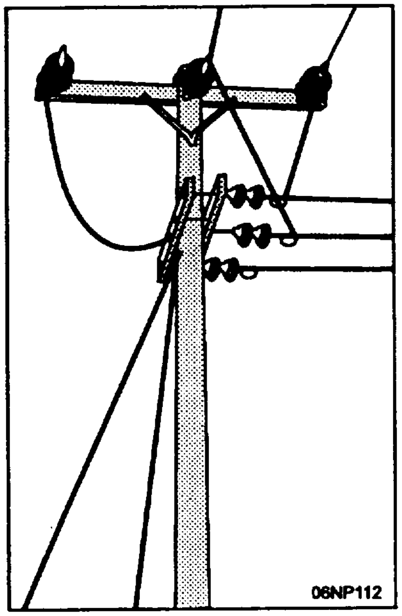


Figure 4-15.—Buck-arm construction.

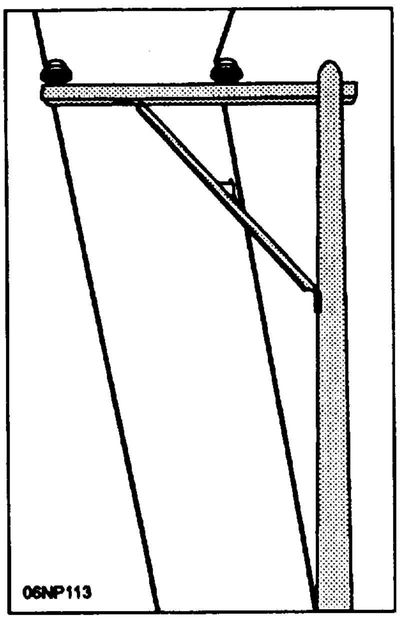


Figure 4-16.—Side-arm construction.

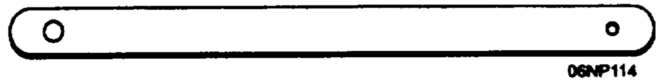


Figure 4-17.—Standard flat-strap crossarm brace.

BUCK ARMS

Buck arms are used at comers and at points when branch circuits are taken off at right angles to the main line (fig. 4-15).

SIDE ARMS

Side arms are used in alleys or other locations when it is necessary to clear buildings. (See fig. 4-16.)

CROSSARM BRACES

Braces are used to give strength and rigidity to the crossarm. Metal crossarm braces are made of either flat bar or light angle iron. The size used varies with the size of the arm and the weight of the conductors. The usual flat-strap brace for ordinary distribution work (fig. 4-17) is 38 inches long and 1/4 by 1 1/4 inches. One end is attached to the crossarm by means of a carriage bolt and the other to the pole by means of a lag screw.

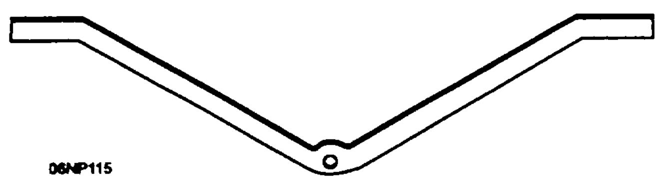


Figure 4-18.—A V-shaped angle-iron crossarm brace.

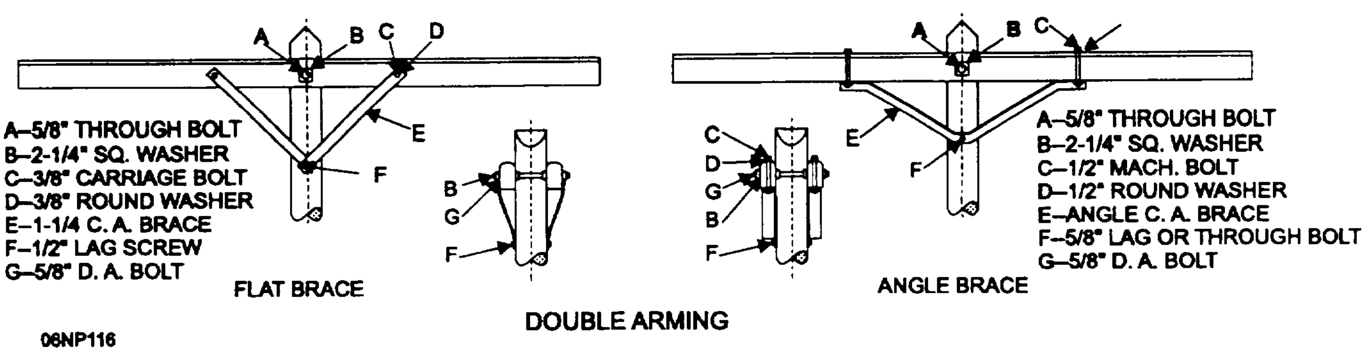


Figure 4-19.—Crossarm brace installation.

One brace extends to each side of the arm. Angle-iron braces are made in one piece and bent into the shape of a V, as shown in figure 4-18. These braces are fitted to the bottom of the crossarm instead of the side as is the flat type. Figure 4-19 gives an example of how these braces are used.

HARDWARE

Line hardware consists of the miscellaneous bolts, nuts, braces, and clamps used to fasten crossarms, guys, and other equipment to the pole. Figure 4-20 shows some samples of common hardware used in power distribution.

INSULATORS

An insulator is a material that prevents the flow of an electric current and can be used to support electrical conductors. The function of an insulator is to separate the line conductors from the pole. Insulators are fabricated from porcelain, glass, and fiber glass, treated with epoxy resins and rubberlike compounds. In determining the size and type you need, you should consider the designed voltage of the circuit, conductor size, length of the pole-line spans, and cost of the various insulators. The most common types of insulators found in Navy use are the pin, post, suspension, and strain insulators.

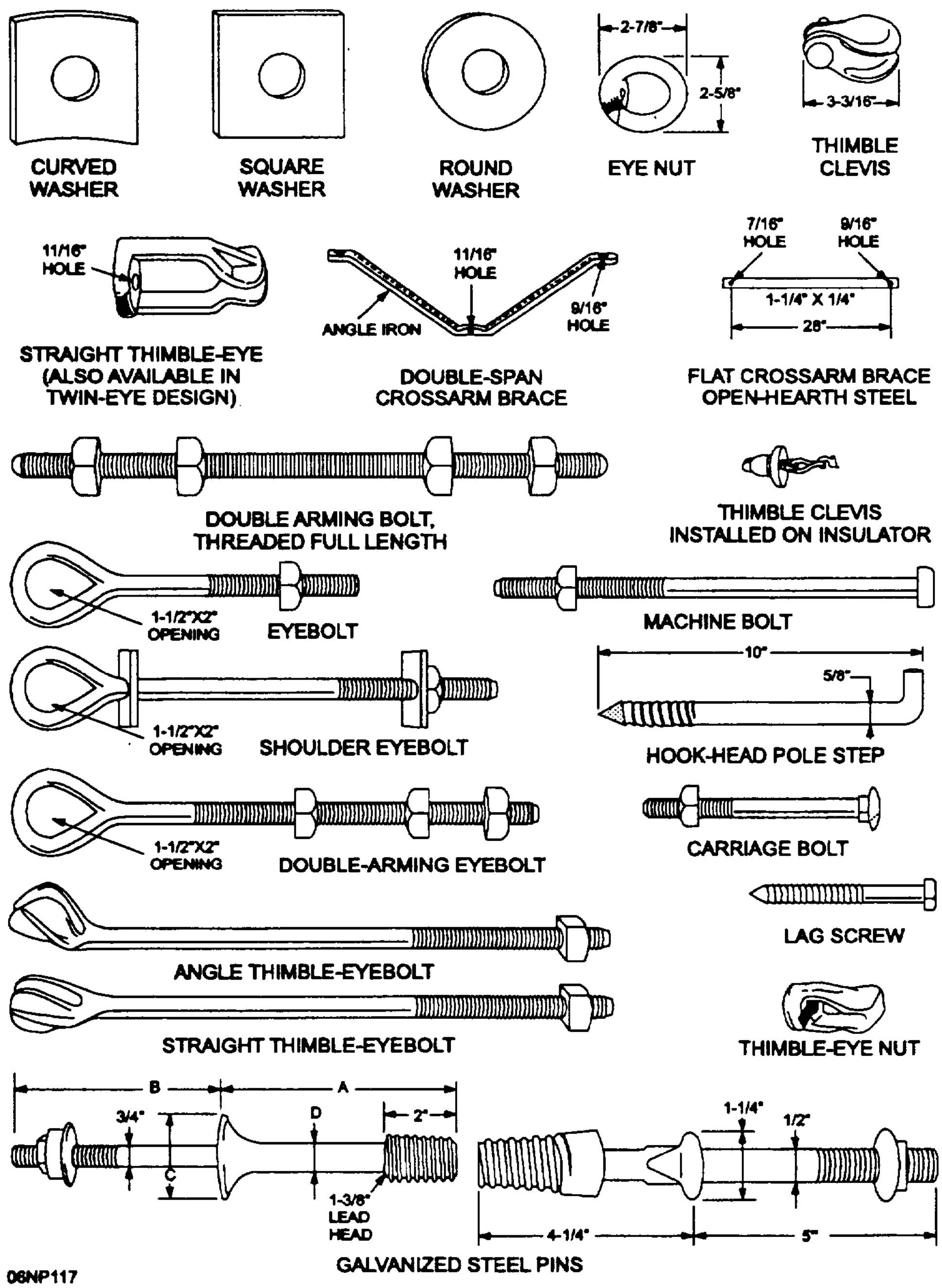
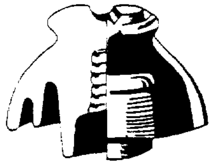


Figure 4-20.—Line hardware.



06NP118

Figure 4-21.—A single-layer porcelain pin insulator.

Pin Insulator

The pin insulator (fig. 4-21) gets its name from the fact that it is supported on a pin. The pin holds the insulator, and the insulator has the conductor tied to it. Pin insulators are made of either glass or porcelain. The glass insulator is always one solid piece. The porcelain insulator is also a one-piece insulator when used with low-voltage lines but will consist of two. three. or four layers cemented together to form a rigid unit when used on higher voltages (fig. 4-22).

Insulator Pins

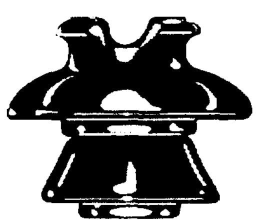
The function of an insulator pin is to hold the insulator mounted on it in a vertical position. Insulator pins are made of wood or metal. Wooden pins are usually made of locust. Locust is durable and retains its strength longer than other woods. Iron and steel pins are used whenever the pins must be extra long, because of high voltage, and whenever the tension on the conductor is great. One make is arranged to encircle the crossarm as a clamp pin—the clamp being held by bolts (fig. 4-23). In many cases. a steel rod is used as the base to permit the use of a 5/8 or a 3/4 hole to be drilled in the crossarm.

Steel pins are in general use. Steel pins have a broad base which rests squarely on the crossarm, as shown in figure 4-24.

The spacing of the pins is generally suited to the voltage of the circuit. The spacing should provide sufficient working space for the lineman. For general distribution work, the spacing is 14 1/2 inches between centers.

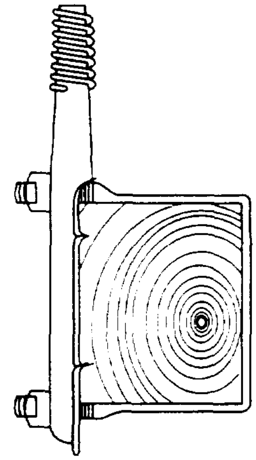
Post-Type Insulators

The post insulators are used on distribution, substation, and transmission lines and are installed on wood, concrete, and steel poles. The line-post insulators are manufactured for vertical or horizontal mounting. The line-post insulators are usually manufactured as one-piece solid porcelain units or fiber glass epoxy-covered rods with metal end fittings and rubber weather sheds. The insulators are fabricated with a mounting base for curved or flat surfaces, and the top is designed for tying the conductor to the insulator or fitted with a clamp designed to hold the conductor. Line-post insulators designed for vertical mounting are mounted on crossarms. This type of construction is often used for long span rural distribution circuits. Figure 4-25 showsdistribution circuits constructed with porcelain horizontal line-post insulators. This armless construction, using post insulators, permits the construction of subtransmission and transmission lines on narrow rights-of-way and along city streets.



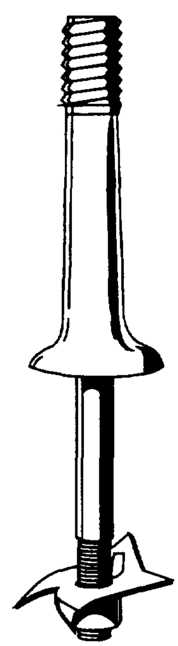
06NP119

Figure 4-22.—A two-layer porcelain pin insulator.



06NP120

Figure 4-23.—Steel clamp pin.



06NP121

Figure 4-24.—Steel pin.

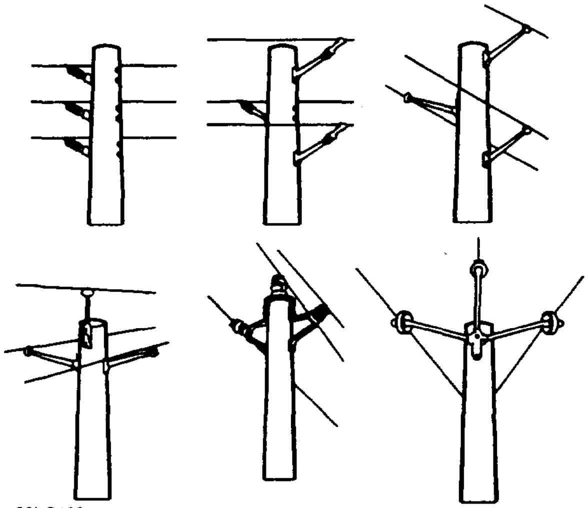

06NP122

Figure 4-25.—Post insulators for armless construction.

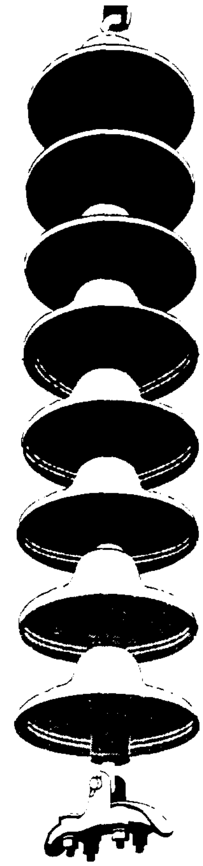

06NP123

Figure 4-26.—Suspension insulator.

Suspension Insulator

In figure 4-26 you see the common suspension insulator. The suspension insulator, as its name implies, is suspended from the crossarm and has the line conductor fastened to the lower end. It is designed for ease of linking units together. Linking of these insulators gives you the versatility of ordering one insulator to be used with varying voltages.

Strain Insulator

The strain insulator looks exactly like the suspension insulator but is designed to hold much heavier physical loads. Strain insulators are used when a pull must be carried as well as insulation provided. Such places occur whenever a line is dead-ended, at comers, at sharp curves, at extra long spans, at river crossings, or in mountainous country. In such places the insulator must not only be a good insulator electrically but it also must have sufficient mechanical strength to counterbalance the forces due to tension of the line conductors. (See fig. 4-27.)

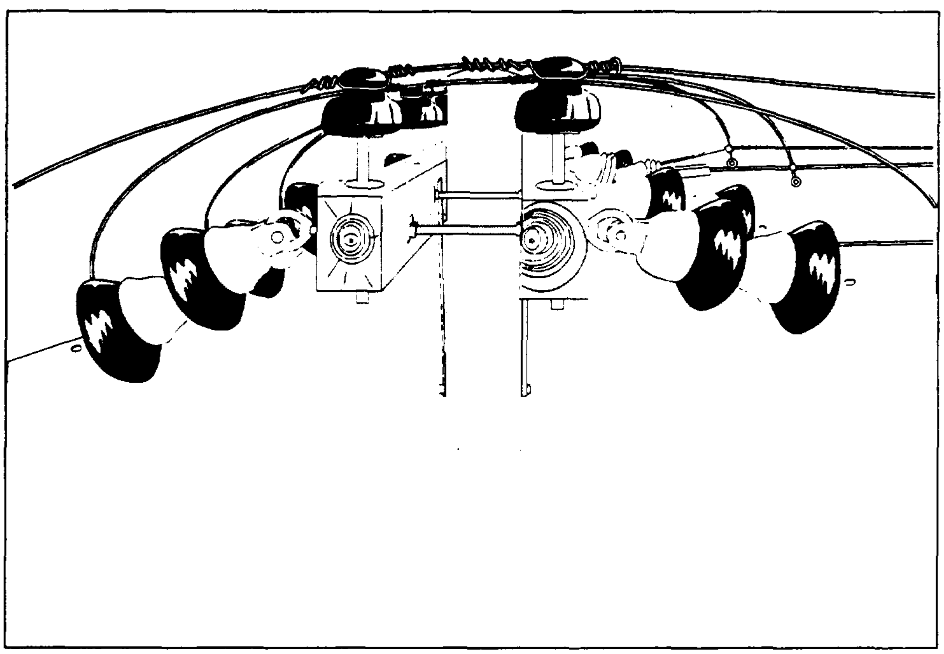

06NP124

Figure 4-27.—Strain insulator.

CONDUCTORS

The wires and cables over which electrical energy is transmitted are made of copper, aluminum, steel, or a combination of copper and steel or aluminum and steel. A conductor is a material that readily permits the flow of an electric current. Materials, other than those mentioned, that conduct electricity are not generally used to make wires and cables because of economic or physical reasons.

Copper Conductors

Copper is the most commonly used line conductor. It conducts electrical current very readily, ranking next to silver. It is very plentiful in nature, it can be easily spliced, and its cost is comparatively low. Three kinds of copper wire are in use: hard-drawn copper, medium-hard-drawn copper, and annealed copper, also called "soft drawn."

For overhead line purposes, hard-drawn copper wire is preferable on account of its greater strength. Medium-hard-drawn copper can be used for distribution lines usually for wire sizes smaller than No. 2.

Aluminum Conductors

Aluminum is widely used for distribution and transmission line conductors. Its conductivity, however, is only about two thirds that of copper. Compared with a copper wire of the same physical size, aluminum wire has 60 percent of the conductivity, 45 percent of the tensile strength, and 33 percent of the weight. The aluminum wire must be 100/60 = 1.66 times as large as the copper wire in cross section to have the same conductivity. When an aluminum conductor is stranded, the central strand is often made of steel that serves to reinforce the cable. Such reinforcement gives added strength for the weight of conductor. Reinforced aluminum cable called ACSR (aluminum-conductor steel-reinforced) is especially suited for long spans.

Copperweld Steel Conductors

In this type of conductor, a protective copper coating is securely welded to the outside of the steel wire. The copper acts as a protective coating to the steel wire, thus giving the conductor the same life as if it were made of solid copper. At the same time, the layer of copper greatly increases the conductivity of the steel conductor, while the steel gives it greater strength. This combination produces a satisfactory yet inexpensive line conductor. Its chief field of application is for rural lines, for guy wires, and for overhead ground wires.

The conductivity of copper-weld conductors can be raised to any desired percentage, depending on the thickness of the copper layer. The usual values of conductivity of wires as manufactured are 30 and 40 percent.

Classes of Conductors

Conductors are classified as solid or stranded. A solid conductor is a single conductor of solid circular section. A stranded conductor is composed of a group of small conductors in common contact. A stranded conductor is used when the solid conductor is too large and not flexible enough to be handled readily. Large solid conductors are also easily damaged by bending. The need for mechanical flexibility usually determines whether a solid or a stranded conductor is used, and the degree of flexibility is a function of the total number of strands. The strands in the stranded conductor are usually arranged in concentric layers about a central core. The smallest number of wires in a stranded conductor is three. The next number of strands are 7, 19, 37, 61, 91, 127, and so forth. Both copper and aluminum conductors may be stranded.

Conductor Sizes

Conductor sizes are ordinarily expressed by two different numbering methods: the American Wire Gauge (AWG) and the circular mil. The AWG conductor sizes are numbered from 30 to 1, then continuing with 0, 00, 000, and 0000 (or 1/0, 2/0, 3/0, and 4/0, respectively). Number 30 is the smallest size and 4/0 the largest in this system. As an example of the actual physical size of the conductors commonly used in transmission and distribution work, refer to figure 4-28.

The circular mil is the unit customarily used in designating the cross-sectional area of wires. A "circular mil" is defined as the area of a circle having a diameter of 1/1000 of an inch. The circular mils of cross section in a wire are obtained by squaring the diameter expressed as thousandths of an inch. For example, a wire with a diameter of 0.102 inches (102 thousandths of an inch) has a circular mils cross section of 102 x 102 = 10,404. Conductors larger than 4/0 AWG are designated in circular mils. These range from 250,000 to 2,000,000 circular mils (250 MCM or 2,000 MCM).

DISTRIBUTION SYSTEMS

A power distribution system is a system that delivers the energy from the generators or transmission lines to the customer. In the Seabees you will be mainly

Gage number	Diameter, in.	Full size, side view	Full size, end view
8	0.1285		
7	0.1443		
6	0.162		
5	0.1819		
4	0.2043		
3	0.2294		
2	0.2576		
1	0.2893		
0	0.3249		
00	0.3648		
000	0.4096		
0000	0.460		

06NP125

Figure 4-28.—American wire sizes for bare copper.

concerned with the construction, maintenance, and repair of the distribution system. Depending on the system, it will consist of a combination of the following components, substations, distribution transformers, distribution lines, secondary circuits, secondary service drops, and safety and switching equipment. The distribution system may be underground, overhead, or a combination of the two.

DISTRIBUTION SUBSTATIONS

Distribution substations change the transmission or generator voltage to a lower level, providing voltage sources for the distribution circuits supplying power to the customers.

DISTRIBUTION TRANSFORMERS

Distribution transformers are installed in the vicinity of each customer to reduce the voltage of the distribution circuit to a usable voltage, usually 120/240 volts.

DISTRIBUTION CIRCUITS

Distribution circuits (primary main circuits) are circuits that originate from the distribution substation. Primary mains are circuits carrying over 600 volts, but generally they operate between 2,400 and 34,500 volts. Primaries can be found in single-phase or three-phase configurations and generally operate as three-phase, three-wire or three-phase, four-wire circuits. Two types of primary circuits are in use today. One, the delta type (A) system, (fig. 4-29) is used when most of the load in

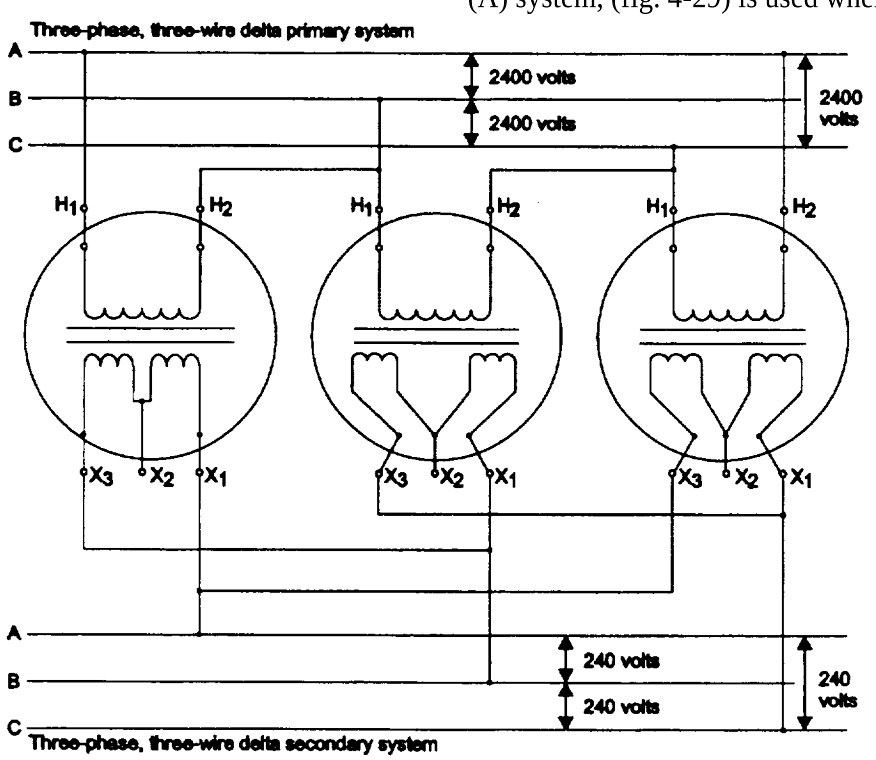


Figure 4-29.—Three-phase delta (A) primary and secondary system.

an area is commercial, consisting of motors and other three-phase equipment. The other type of circuit is called the wye (Y) system (fig. 4-30) and is used primarily for residential use.

SECONDARY CIRCUITS

Secondary circuits (secondary mains) are circuits that originate from the secondary windings of a distribution transformer and are 600 Vac or less. The secondary circuits are also configured either delta (A) (fig. 4-29) or wye (Y) (fig. 4-30) and are also used for the same type of loading as the primary circuits.

Secondary circuits are either three phase—meaning those with three live conductors—or single phase, which can be one live conductor and a neutral or two live conductors and a neutral.

SERVICE DROPS

A service drop is the combined conductors used to provide an electrical connection between a secondary distribution circuit and a user's facility. There are different ways of installing the service drop. Some typical secondary racks used to install service drops are shown in figure 4-31. Whether using the racks with individual conductors or self-supporting service cable, known as triplex or quadraplex, to provide a service drop, you must maintain a minimum aboveground distance. Aclearance of 12 feet over lawns or walkways accessible to pedestrians and 18 feet over roads or alleyways subject to truck traffic as recommended by the NEC©, as shown in figure 4-32. When the nearest distribution pole is over 125 feet from the facility to be connected, an intermediate support pole must be provided.

CONTROL AND PROTECTIVE DEVICES

A power distribution circuit, like any other electrical circuit, requires the use of special devices to provide control and to protect the system from internal or external influences that may damage the circuit.

DISTRIBUTION CUTOUTS

A distribution cutout provides a high-voltage mounting for the fuse element used to protect the distribution system or the equipment connected to it.

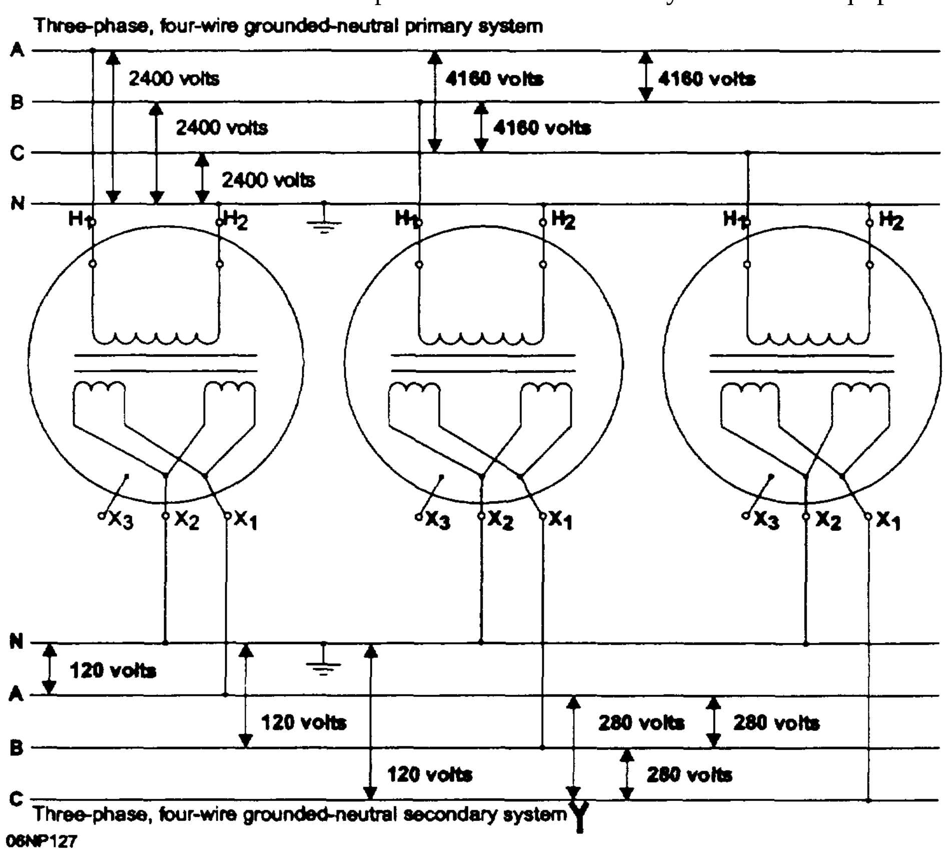


Figure 4-30.—Three-phase wye (Y) primary and secondary system.

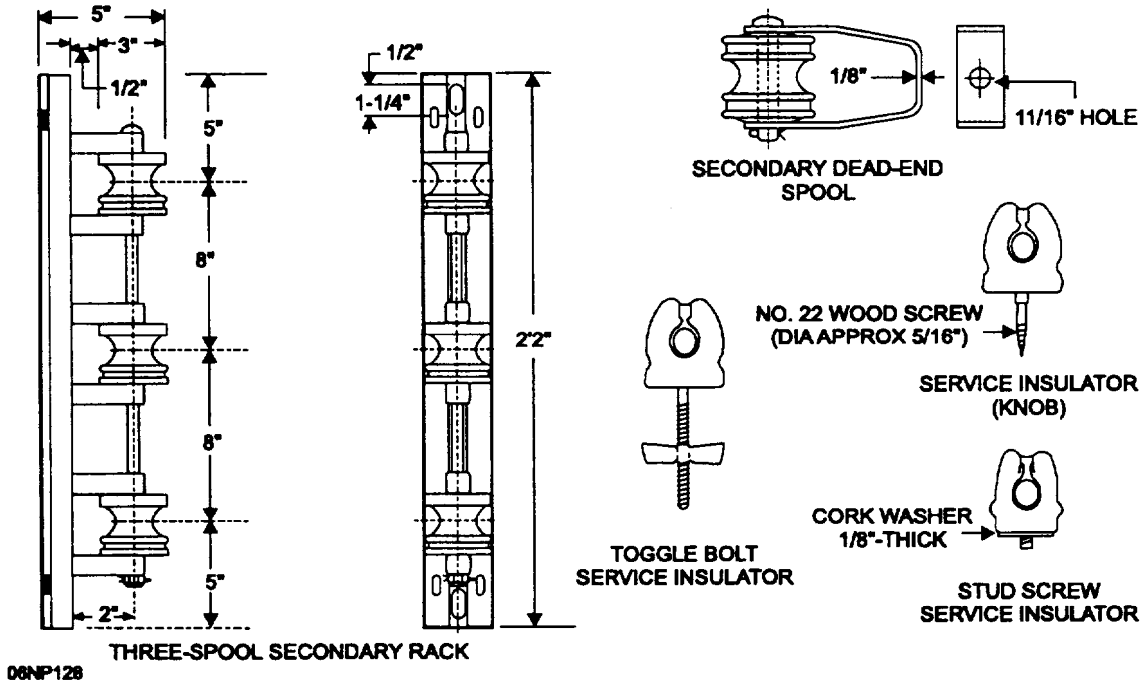


Figure 4-31.—Secondary racks and dead-end spools.

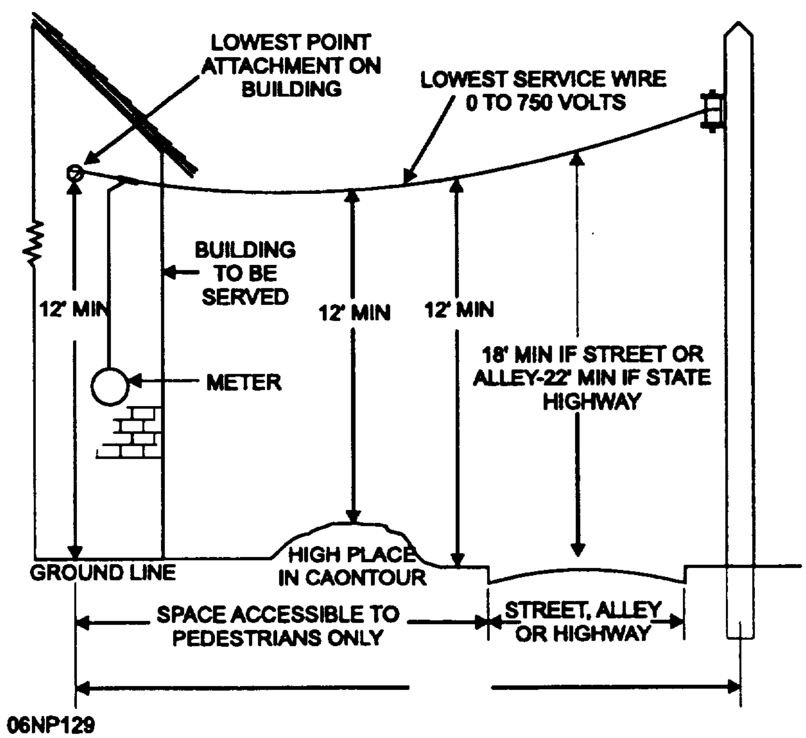


Figure 4-32.—Minimum ground clearances of service drops

Figure 4-33 shows an open types of distribution cutout being closed. Distribution cutouts are used with installations of transformers, capacitors, cable circuits, and sectionalizing points on overhead circuits.

Enclosed Distribution Cutout

An enclosed distribution fuse cutout is one in which the fuse clips and fuse holder are mounted completely within an enclosure (fig. 4-34, view A). A typical enclosed cutout has a porcelain housing and a hinged door supporting the fuse holder. The fuse holder is a hollow vulcanized-fiber expulsion tube. The fuse link is placed inside the tube and connects with the upper and lower line terminals when the door is closed. When the fuse blows or melts because of excessive current passing through it, the resultant arc attacks the walls of the fiber tube, producing a gas that blows out the arc. The melting of the fusible element of some cutouts causes the door to drop open, signaling to the lineman that the fuse has blown.

Open-link Distribution Cutout

This type of cutout differs from the open cutout in that it does not use the fiber expulsion tube (fig. 4-34, view B). The fuse link is supported by spring terminal contacts. An arc-confining tube surrounds the fusible element of the link. During fault clearing, the spring contacts provide link separation and arc stretching. The arc-confining tube is incorporated as part of the fuse link.

Open Distribution Cutout

Open cutouts are similar to the enclosed types, except that the housing is omitted (fig. 4-34, view C). The open type is made for 100- or 200-amp operation. Some cutouts can be up rated from 100 to 200 amps by using a fuse tube rated for 200-amp operation.

Lightning Arresters

Lightning arresters are designed to permit normal circuit operations at designed voltages, yet conduct any potentially destructive higher voltage, such as lightning

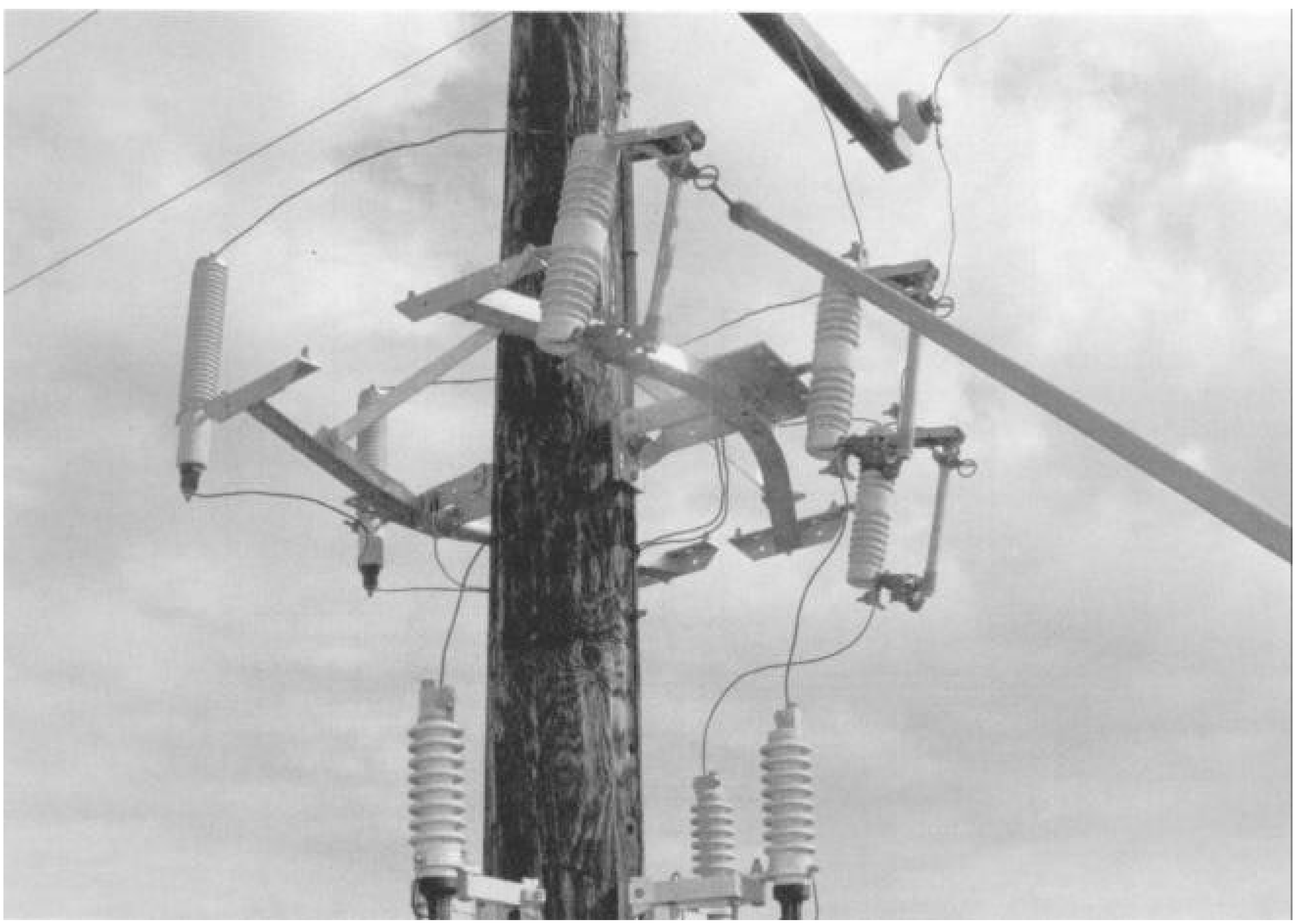


Figure 4-33.—Distribution cutout.

produces or transient currents, to ground without injury to line insulators, transformers, or other connected equipment. Use of lightning arresters is essential in all areas of power line construction. These include distribution, secondary, intermediate, and station distribution. The four different specifications of arresters, mentioned above, have different sparkover voltages, current discharge capabilities, and maximum surge discharge capabilities.

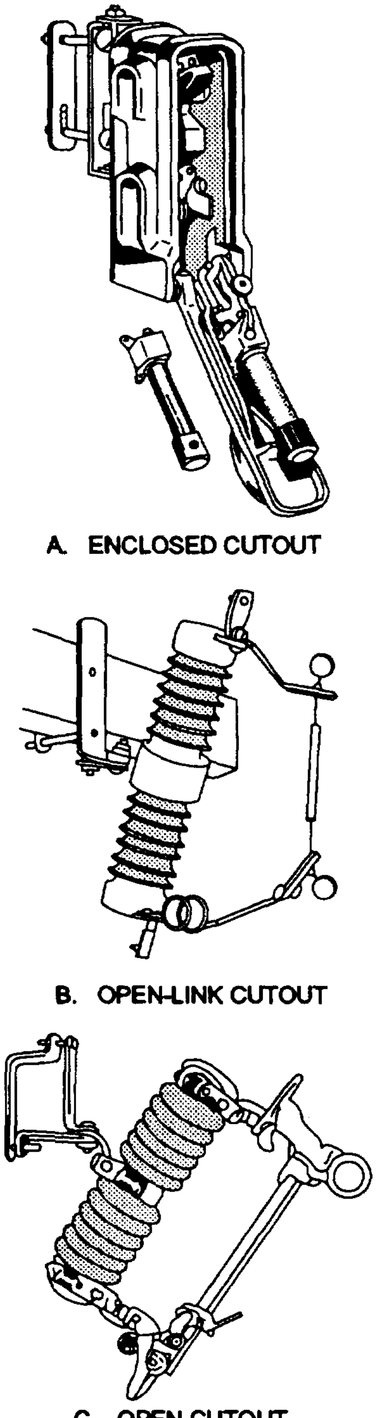


Figure 4-34.—Distribution cutouts (fused).

Secondary arresters are used on service and other low-voltage alternating-current circuits. Distribution arresters are used on primary distribution systems to protect insulators, distribution transformers, and other equipment. Intermediate type of lightning arresters are often used on substation exit cables and other locations on the distribution system, needing a high level of lightning and surge protection. Substation types of arresters are used in substations and generating stations to provide a high level of surge protection for the major pieces of equipment. Surge voltages can be generated by operating switches in the electric transmission system as well as by lightning.

Various types of lightning arresters are in use today. The valve, pellet, and air gap (fig. 4-35) are the most common and likely-to-be-seen types in the field.

SWITCHES

A switch is used to disconnect or close circuits that may be energized. High-voltage switches are operated remotely using a variety of mechanisms or manually. Depending on their purpose in the system and their physical makeup, switches are divided into three general classes: air, oil, and vacuum switches. These three classes can be further subdivided (depending on their function) into what is referred to as disconnects, circuit breakers, or reclosers.

Air Switches

As their name implies, air switches are switches whose contacts are opened and use air to insulate their contacts when current flow is interrupted.

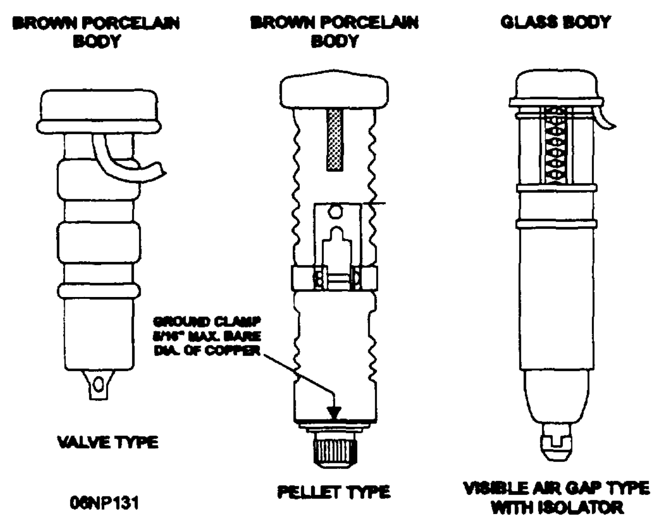


Figure 4-35.—Types of lightning arresters.

An **air-circuit breaker switch** can have both blade and stationary contacts equipped with arcing horns (fig. 4-36). These horns are pieces of metal between which the arc forms when a circuit-carrying current is opened. These arc horns are drawn further and further apart until the arc finally breaks. Air-break switches are usually mounted on substation structures or on poles and are operated manually from the ground. In a three-phase circuit all three switches—one for each phase—are opened and closed together.

An **air-disconnect switch** is not equipped with arcing horns or other load-break devices. It therefore cannot be opened while current is flowing (fig. 4-37). If the disconnect switch should be opened while current is flowing in the line, an arc would likely be drawn between the blade and its stationary contacts. The hot arc would melt part of the metal, thereby damaging the switch. The purpose of a disconnect switch is to isolate a line or a piece of equipment for the purpose of making the disconnected line or equipment dead electrically, thus making it safe for repairs, tests, or inspections.

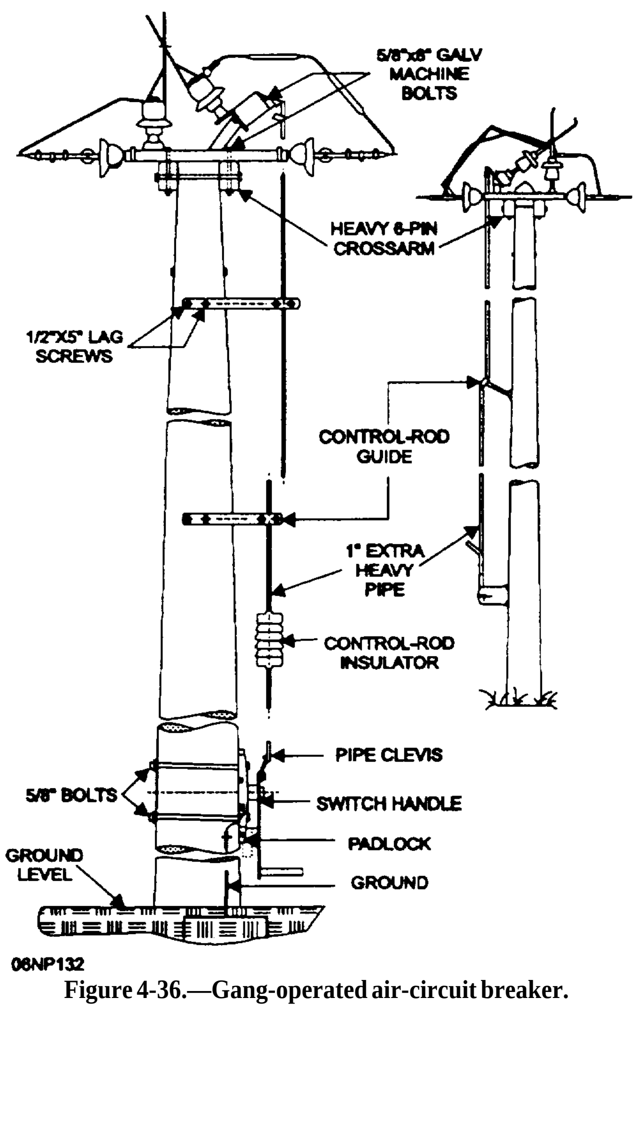


Figure 4-36.—Gang-operated air-circuit breaker.

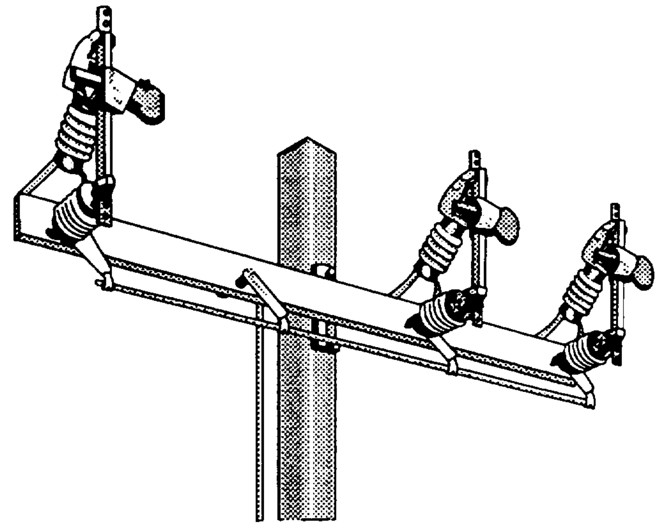


Figure 4-37.—Air-disconnect switch.

Oil Switches

An oil switch is a high-voltage switch whose contacts are opened and closed in oil. Oil switches may be used as disconnect, circuit breakers, or reclosers. The switch is actually immersed in an oil bath, contained in a steel tank, as shown in figure 4-38. The reason for placing high-voltage switches in oil is that the oil may help to break the circuit when the switch is opened. With high voltages, a separation of the switch contacts does not always break the current flow, because an electric arc forms between the contacts. If the contacts are opened in oil, however, the oil helps to quench the arc. Oil is an insulator and, therefore, helps to quench the arc between the contacts. The three lines of a three-phase circuit can be opened and closed by a single oil switch. If the voltage is not extremely high, the three poles of the switch are generally in the same tank. But if the voltage of the line is high, the three poles of the switch are placed in separate containers.

Circuit Reclosers

The circuit reclosers most commonly used in power distribution are electronic reclosers, oil reclosers, or vacuum reclosers. These reclosers basically operate in the same manner.

Reclosers come in single- or three-phase models and can either be pole-mounted or installed in a substation. These reclosers are for overload protection and are designed to open a circuit in an overload condition and then automatically reclose the circuit. If the fault on the system has cleared, the recloser remains closed. If the fault has not cleared, the recloser trips

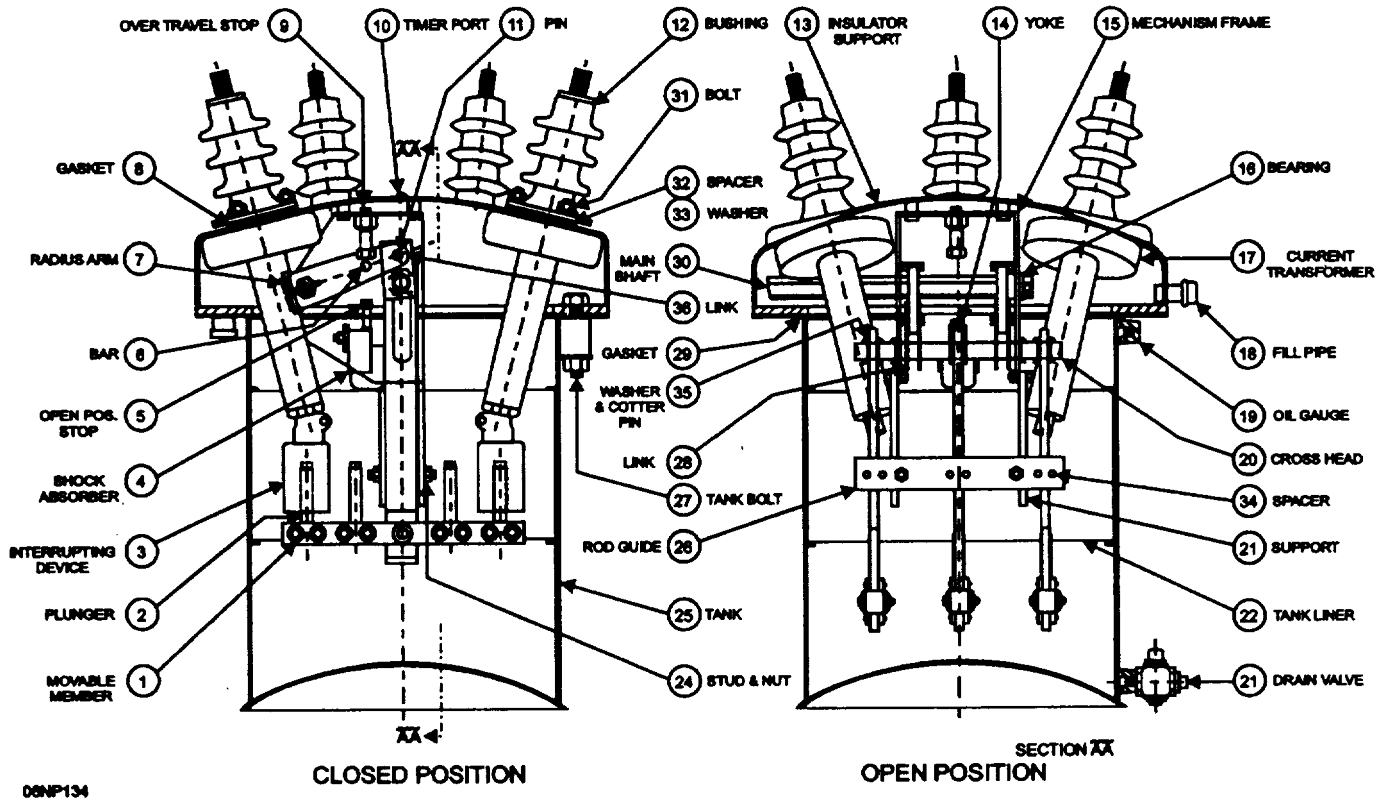


Figure 4-38.—Internal and external components of an oil circuit breaker.

again, and after a short interval, recloses the system for the second time. If the fault has not cleared on the third time, the system will open and stay open. The recloser also has a manual lever or electronic control to set the recloser on what is commonly referred to as "single-shot" action. When linemen are working in the general area of a circuit, they place the recloser in the single-shot mode. Then should a mistake be made, causing the circuit to trip, it will not reset itself automatically.

POWER DISTRIBUTION EQUIPMENT

The equipment most commonly used for construction and maintenance of Navy power distribution systems consists of the utility truck, aerial bucket truck, earth auger, pole trailer, wire trailer, and various manual lifting devices.

UTILITY TRUCK

The utility truck is a specially designed piece of equipment that, used effectively, provides the lineman with transportation, tool and material storage, and the capability to accomplish most tasks safely, efficiently, and quickly.

AERIAL BUCKET TRUCK

The aerial bucket truck comes in various shapes and sizes. It is used at most naval installations or battalions for maintenance or construction of the power distribution system. The aerial bucket truck provides the power lineman with an efficient, comfortable, and safe working platform and is especially useful in areas where concrete or steel poles are used.

The aerial bucket truck has storage bins for material and tools. Depending on the make of the vehicle and the desired use, the truck may have a telescoping single- or double-arm boom, it may be equipped with hydraulic outrigger jacks for stability, and the bucket may be powered by the truck engine or an auxiliary engine mounted on the back of the truck. Because of the various designs of bucket trucks, each one will have some capabilities that are not common to all. When using an aerial bucket truck, you should follow the manufacturer’s operation, maintenance, and testing procedures at all times. This promotes smooth operation and extends the usable life of the vehicle. When you are operating the bucket, safety of operation should be your prime concern. Although the bucket is insulated, all personnel should maintain a constant awareness of the hazards of operating in and around high-voltage power lines.

EARTH AUGER

Another high-production piece of line equipment is the earth auger. This truck-mounted unit, as shown in figure 4-39, is designed to dig holes up to 7 feet deep and comes with different sizes of auger bits to enable you to vary the diameter of the hole. The auger truck usually has a winch attached that enables it to be used to set poles and other attachments that allow it to install some types of guying anchors. These features are normally used when a framing crew is assigned with the auger truck. They install all line hardware on the pole before they set it in place (except when the hardware is too heavy) and place the anchors. This method is used when long power lines are being constructed. It requires less pole time for the linemen and enables them to devote more time to stringing conductors, installing the line equipment, and making connections on the poles.

MANUAL LIFTING EQUIPMENT

There are many different types of manual lifting equipment used in line work. Some of the various types and uses of manual lifting equipment are discussed in the paragraphs below.

Pole Gin

The pole gin, as shown in figure 4-40, is designed for temporary attachment to a pole. It provides a secure point for attaching other lifting equipment, such as a block and tackle used in lifting heavy objects, for mounting on the pole. Transformers, capacitors, regulators, heavy lighting fixtures, and heavy crossarms are a few examples of the types of equipment that may be lifted by using the pole gin.

When you are lifting a distribution transformer, it should be handled carefully. Bushings and other equipment on the transformer can be damaged easily. The windings of the transformer may be damaged if the

Figure 4-39.—Earth auger.

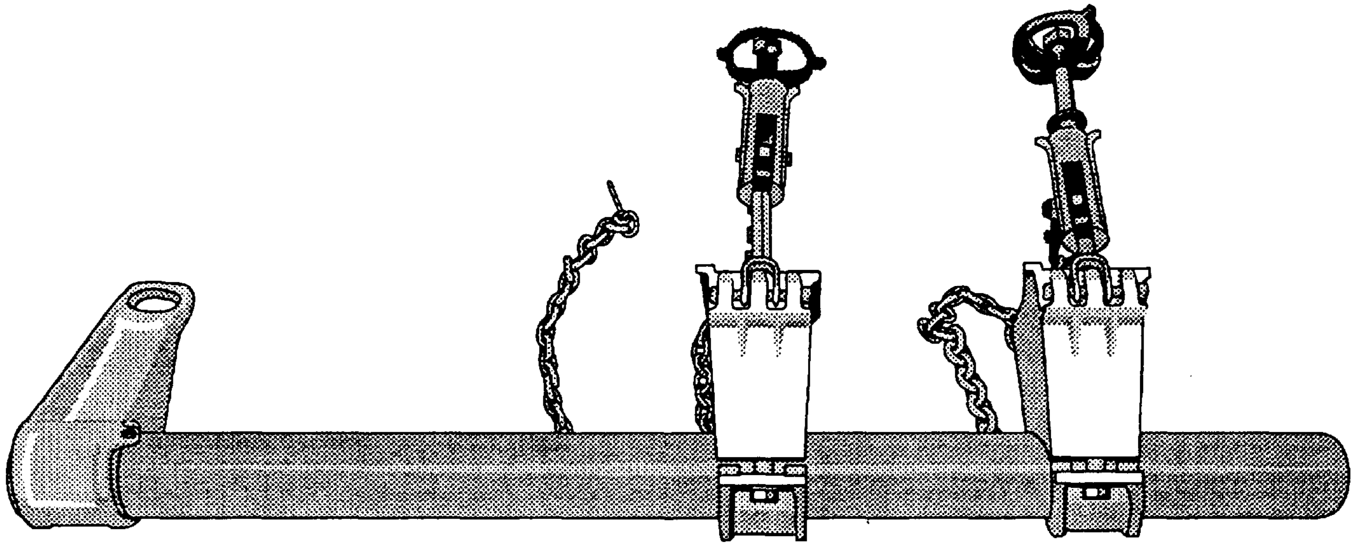


Figure 4-40.—Pole gin.

transformer is dropped or severely jolted. The lifting equipment, including the slings, should be carefully inspected before the operation is started. The linemen and groundmen should stay clear, while the transformer is raised into position. Appropriate personal protective equipment must be worn at all times.

Block and Tackle

Block and tackle are used for applying tension to line conductors when sagging in, for applying tension to guy wires when hoisting transformers, and for other general-purpose hoisting. The use of block and tackle has two advantages: (1) the user can stand on the ground and pull downward while hoisting or lifting a load and (2) the manual force applied need only be a fractional part of the load lifted.

To find the pull required to lift a given weight with a block and tackle, divide the weight by the number of ropes running from the movable block. The lead line, or haul line, is not to be counted. Some friction loss always occurs around the sheaves. This can be estimated at 10 percent per sheave and added to the load to be lifted. The load that may be lifted is therefore the mechanical advantage times the safe load on the rope. Safe lifting load requirements for rope can be found in chapter 3. The block and tackle, as shown in figure 4-41, is called a four part block and tackle because it has four times the mechanical advantage for lifting an object. Again this is determined by the number of ropes (four), not counting the hauling line running from the movable block.

Lifting Straps and Slings

Whether lifting with the block and tackle or a winch, you will also need lifting straps or slings to secure the equipment being lifted to the lifting apparatus.

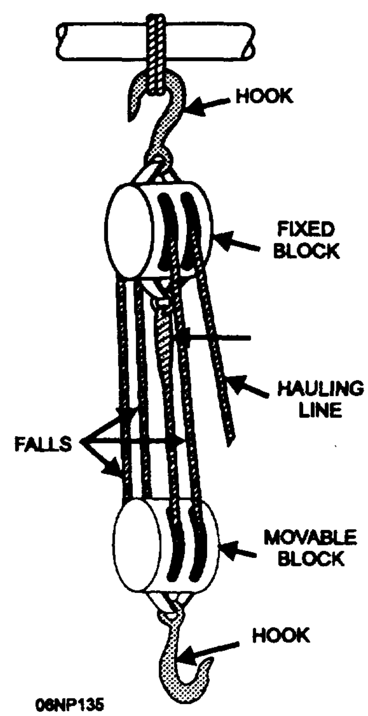


Figure 4-41.—Block and tackle.

Figure 4-42 shows examples of a lifting strap and a chain. For a detailed explanation of uses, strengths, and various types of lifting straps and slings, refer back to chapter 3.

Snatch Block

A snatch block (fig. 4-43) is a single sheave block made so that the shell opens on the side at the base of the hook to permit a rope or line to be slipped over a sheave without threading the end of it through the block. Snatch blocks ordinarily are used when it is necessary to change the direction of the pull on a line.

Handline

While working on a power pole, every lineman should carry a handline. It can be used for lifting or lowering smaller objects and also for holding transformers and other equipment away from the pole as it is being raised. The handline is usually made of 1/2-inch manila rope, approximately 30 to 35 feet long, and has a manufactured or self-made metal hook attached to one end. The handline is personal equipment and can be configured to best suit the individual or the job to be accomplished.

Pulley Line

The pulley line, as shown in figure 4-44, is another lifting tool and is used to replace the handline when large quantities of material must be lifted to the top of the pole. When the pulley line is used in this way, the lineman can continue working, while the materials are being supplied by the groundman.

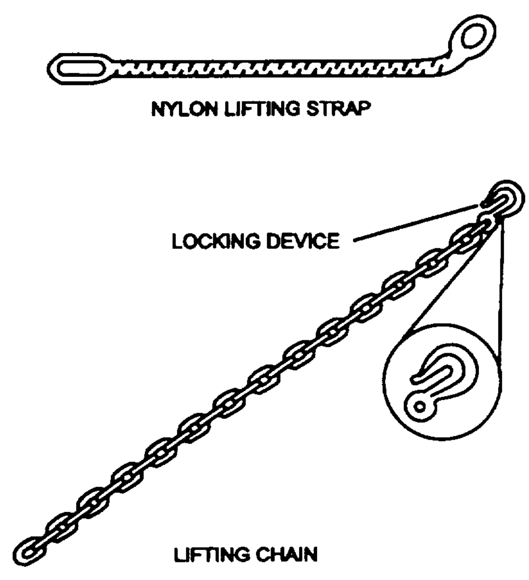


Figure 4-42.—Lifting strap and chain.

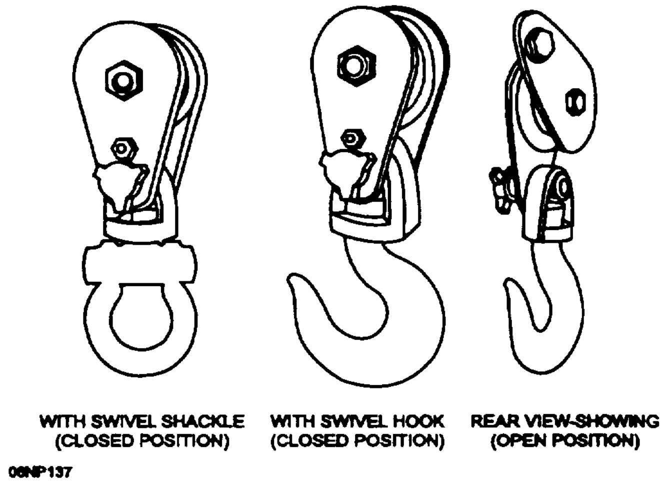


Figure 4-43.—Top dead-end snatch block.

Pole Jack

Another manual lifting device is the pole jack, as shown in figure 4-45. It is designed for easy attachment and removal from the pole and provides an unpowered mechanical lift that is used to straighten or remove power poles.

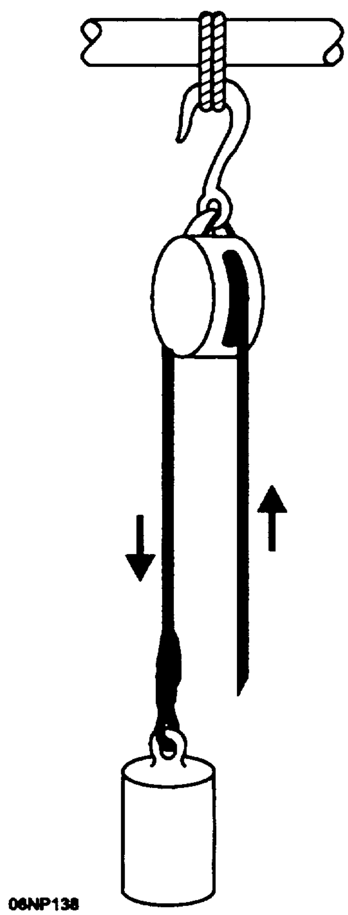


Figure 4-44.—Pulley line.

Come-along

The come-along, a pulling tool, is normally used for dead-ending line conductors or installing guy wires (fig. 4-46). It is designed with a ratchet action that can be used to pull or release strain by placing the forward or reverse lever in the desired setting.

Grips

The wire grips, as shown in figure 4-47, view A, are engineered to grip the wire and hold it when pulling or slow release is desired. It is used in the sagging operation and also in applying strain to the guy wire during installation. Different designs of wire grips are used, and you should ensure that you have the right one before you attempt to pull with them.

A grip that is similar to the wire grip is called the bulldog grip. This grip, as shown in figure 4-47, view B, is made for pulling large objects, such as ground rods. When pulling conductors, do not use this grip; it will cause damage that cannot be repaired.

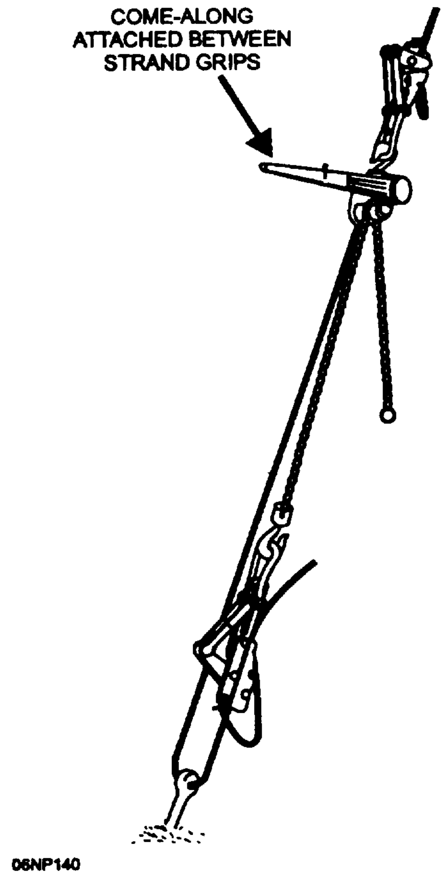


Figure 4-46.—Come-along.

SETTING POLES AND INSTALLING HARDWARE AND CONDUCTORS

Constructing a pole line involves such functions as framing; setting poles; and installing crossarms, hardware, and conductors. The paragraphs that follow will cover these elements of work and give you a better understanding of how the construction is accomplished.

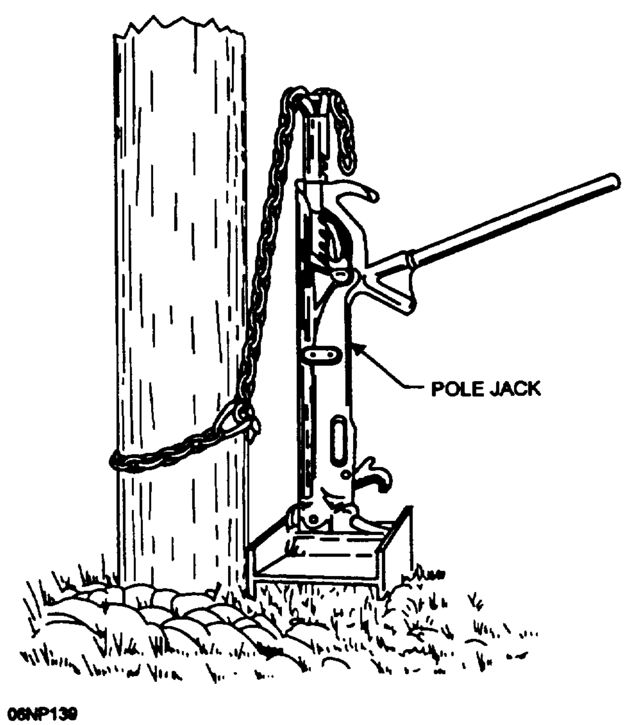


Figure 4-45.—Pole jack.

FRAMING POLES

Framing a pole consists of the following actions: determining the face and back of the pole, cutting the roof and gain, and drilling holes for mounting hardware.

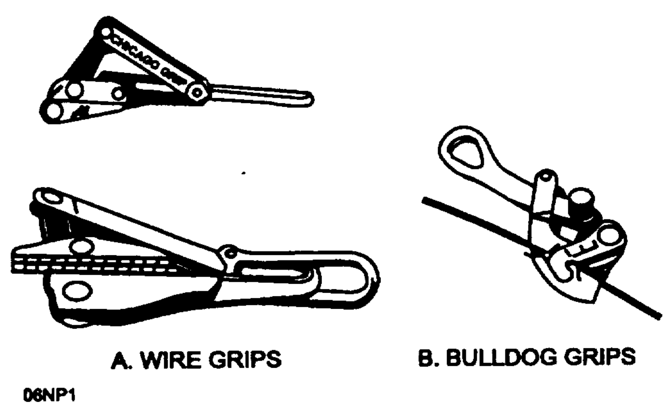


Figure 4-47.—Grips.

Figure 4-48 shows that the face of any pole is on the inside of any curve the pole may have. This allows the wire strain on the crossarm to be against the curve of the pole. This also dictates positioning of the gain on the face of the pole, except for gains on comer poles, when lower crossarms are mounted at a 90-degree angle to the main distribution line.

The roof or top of the pole (fig. 4-48) is cut sloping at a 15-degree angle from the face to the back of the pole; however, on the new pressure-treated poles, roofs are not required.

A gain should be one-half inch deep in the center, slightly concave, and located 12 inches from the top of the pole. The width of the gain should be the height of the crossarm to be used. Spacing of succeeding gains depends on the voltage of the lines to be placed on that level. This information is contained in the project specifications and drawings for any new work for which you are tasked.

To drill holes for mounting crossarms, use a template that can be used to mark the center, or draw two diagonal pencil lines across the gain. The intersection of these two lines determines the center of the gain and the place to drill the hole. The nominal size hole is 1 1/16 inch for a 5/8-inch through bolt.

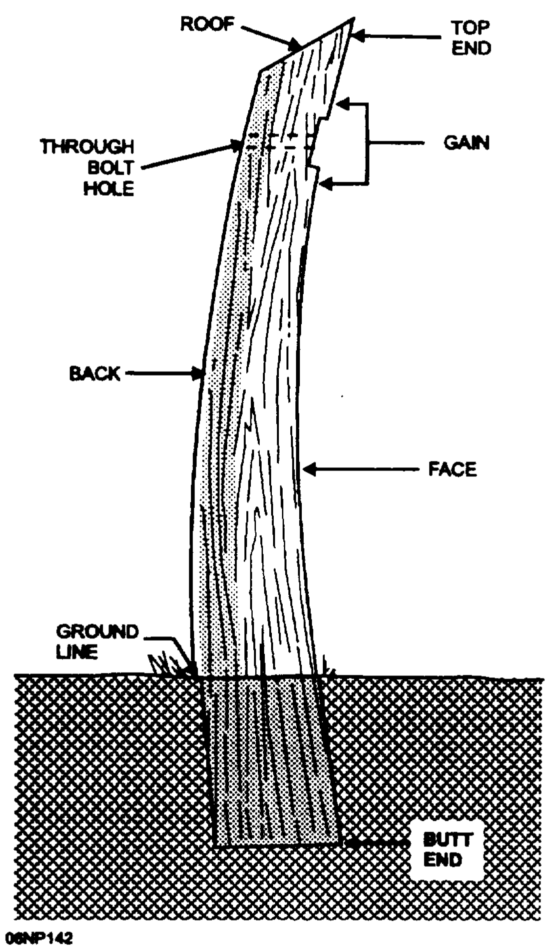


Figure 4-48.—The parts of a pole.

INSTALLING POLES

The depth for a pole hole depends on the length of the pole and the composition of the soil. A hole in firm, rocky terrain does not need to be as deep as a hole in soft soil. Table 4-1 gives recommended depths for poles from 20 to 60 feet long in firm soil and in rock.

A pole set in sandy or swampy soil must be supported by guys or braces, or by cribbing. "Cribbing" means placing some firm material around the part of the pole that is below the ground. One method of cribbing is to sink an open-bottom barrel in the hole, set up the pole in the barrel, and then fill the space around the base of the pole with concrete or small stones after the pole has been plumbed (brought to the vertical). Another method of cribbing is shown in figure 4-49.

There may be a power-driven hole digger available, but in the absence of one of these, the holes must be dug by hand tools (fig. 4-50). You use a "digging bar" to loosen the soil. You can remove about the first 2 feet of depth with a short-handled shovel. Below that, you loosen the earth with an earth auger or long-handled shovel, and haul it up with a long-handled device, called a spoon.

A hole should have a diameter about 6 inches larger than that of the base of the pole to allow room for tamping backfill. It should be a little larger at the bottom to allow for plumbing the pole.

ERECTING POLES

When a earth auger is available, the job of erecting poles is relatively simple. A sling is placed around the approximate midpoint of the pole, and the winch heaves it up, and it is held in place by a pole claw (fig. 4-51).

Table 4-1.—Depth for Setting Poles in Soil or Rock

LENGTH OF POLE (ft)	SETTING DEPTH (ft)	
	IN SOIL	IN ROCK
20	5.0	3.0
25	5.5	3.5
30	5.5	4.0
35	6.0	4.0
40	6.0	4.0
45	6.5	4.5
50	7.0	4.5
55	7.5	5.0
60	6.0	5.0

06NP143

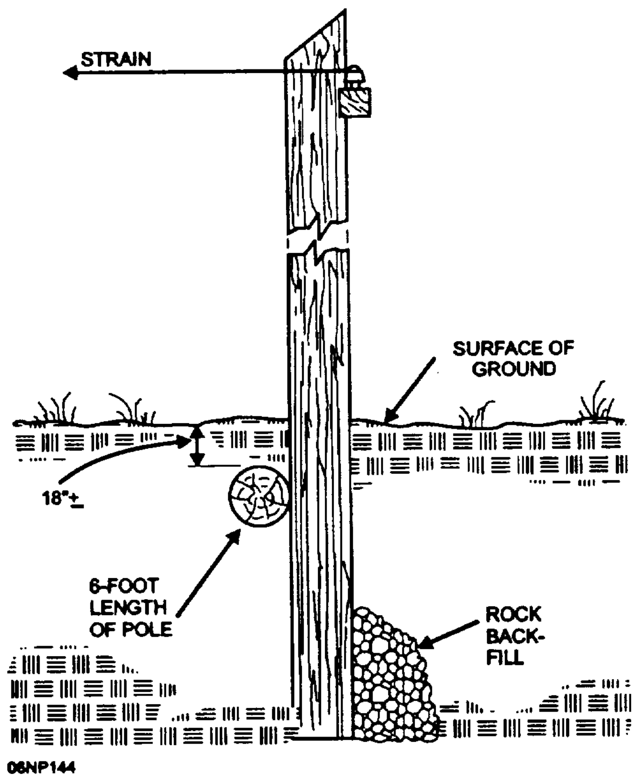


Figure 4-49.—Cribbing a pole with stones and a log.

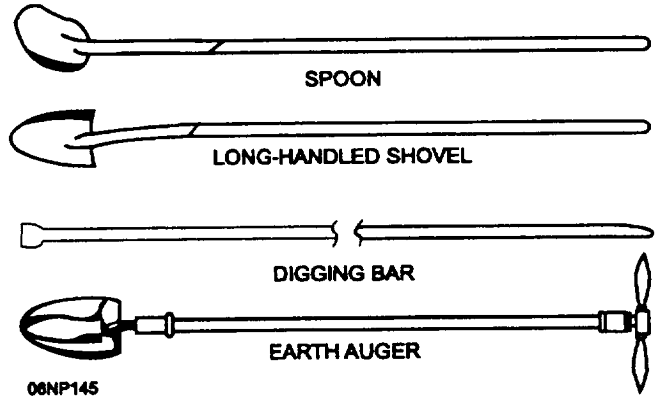


Figure 4-50.—Digging tools.

The truck then proceeds to the hole or is pre-positioned at the hole site, and the base of the pole is guided in as the winch lowers away (fig. 4-52). Since the butt, or base, is heavier than the top end, the pole is raised to an almost vertical position.

In the absence of this equipment, the pole must be "piked up"—meaning that the pole is placed with the base adjacent to the hole and the upper end supported on either a "mule" or a "jenny." A jenny is a wooden support made in the form of an X, and a mule is a wooden support made in the form of a Y. The upper end

Figure 4-51.—Pole positioning before being set.

Figure 4-52.—Auger truck setting a pole.

is then "piked" into the air by crew members using pike poles. A cant hook (peavy), pike pole, and pole support (mule) are shown in figure 4-53. Figure 4-54 shows the proper way to position a pole manually for erection.

The procedure for piking up a pole is shown in figure 4-55. The "butt man" holds and guides the butt of the pole with a cant hook (or peavy) (fig. 4-53). This is a handle with a hook designed to grasp the pole when pressure is applied to the handle. As the upper end of the pole is raised, a crew member keeps the jenny or mule in approximate contact by moving it toward the butt. The "butt board" is a length of plank set in the hole and long enough to protrude above the surface. It prevents the

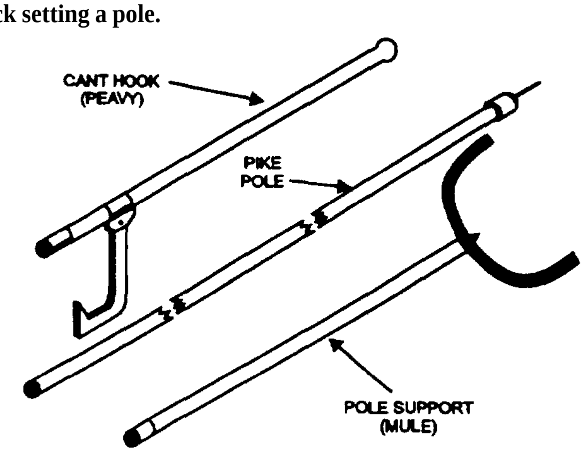


Figure 4-53.—Pole tools.

Figure 4-54.—Manually positioning a pole.

butt of the pole from sliding past the hole and also prevents the butt from caving in the side of the hole. After the pole has reached an upright position, it is "faced"—meaning that it is rotated with the cant hook to bring the crossarm gain to proper position. On a straight line it is the custom to set adjacent poles with crossarms

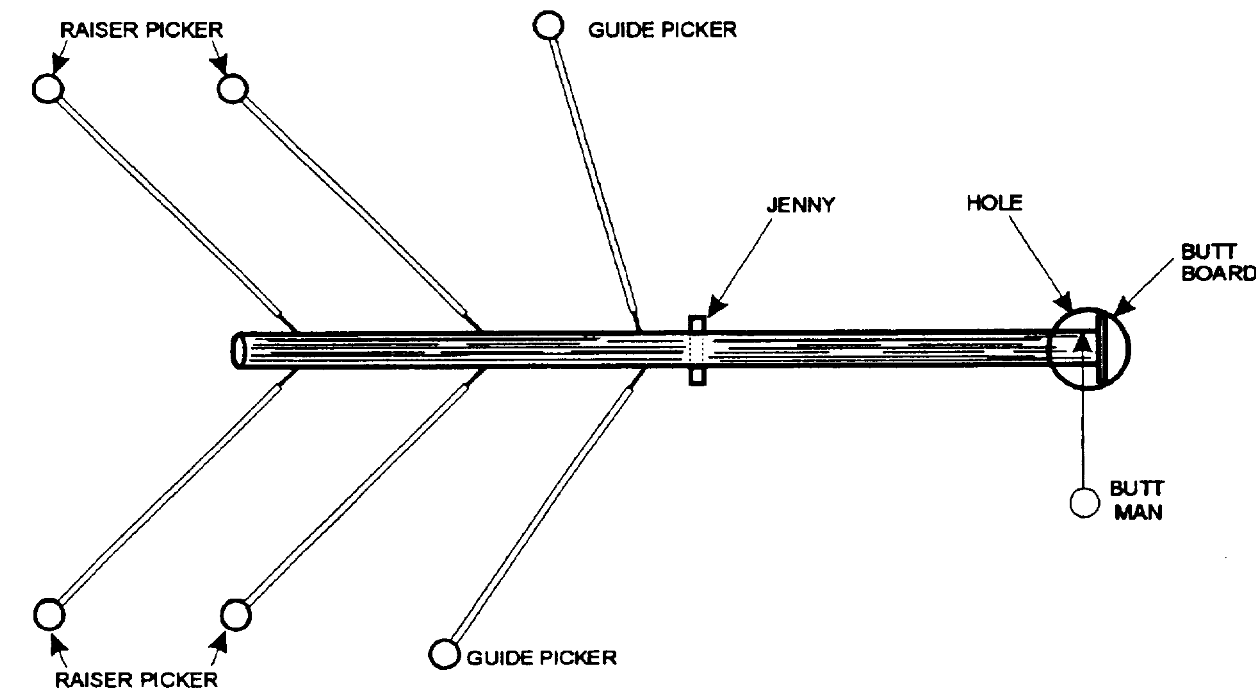


Figure 4-55.—Piking up a pole.

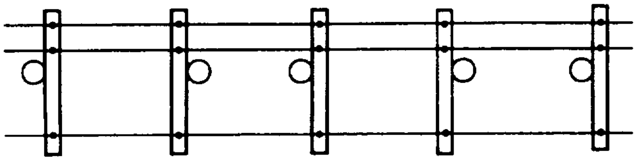


Figure 4-56.—Poles facing in a straight line.

facing in opposite directions, as shown in figure 4-56. This procedure, called facing "gain to gain" or "back to back," provides for maximum strength in the line.

Poles are always faced in the direction of hills, curves, and dead ends, as shown in figure 4-57. This is done to allow the most strain to be placed on the face and against the curve of the poles.

After the pole has been faced, it must be plumbed vertical. This is done by four pikers on four sides of the pole, acting on signals given by one crew member who sights along the line and another who sights from one side. In some cases, a small amount of rake or lean (approximately 12 inches) is left to allow for a wire strain or the normal give of a guy.

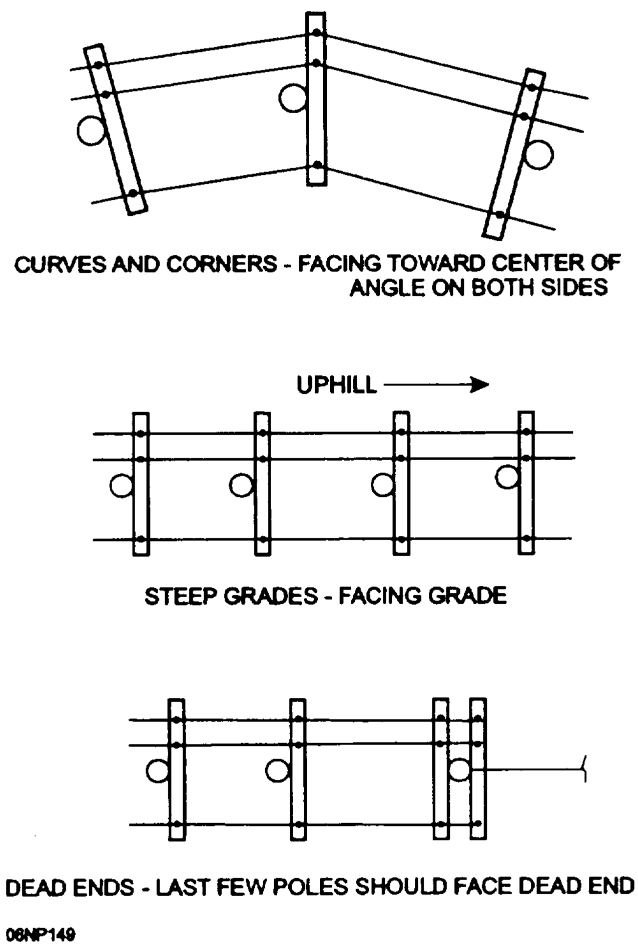


Figure 4-57.—Pole facing.

After the pole has been plumbed, the hole is backfilled and the backfill tamped down firmly. Backfilling is done gradually, in shallow layers, with each layer thoroughly tamped down. Usually two or three crew members tamp, and one shovels. When the hole has been filled to the ground line with tamped backfill, the remaining excavated soil is banked in a mound around the base of the pole to allow for subsequent settling (fig. 4-58).

WARNING

As a pole is being raised, it is safest to assume that at any moment something may slip or break Stand as far away from the pole as possible if you are not in the raising crew.

The pike-pole method of setting poles should not be used unless there are enough crew members to do the work safely. In using pikes the crew must stand far enough apart so that they will not interfere with each other. Never brace a pike pole on your stomach. If the pole should happen to shift your way, you would not be able to get clear. Unmanned pikes alone should not be relied upon to support a pole, while a crew member is on it. Pike-pole tops should be kept covered at all times except when actually in use.

Crew members should not be on poles, while they are being plumbed, canted, or tamped.

INSTALLING GUYS

Guys are assembled using seven-strand galvanized steel guy wire, a strain insulator (of a different design from and not to be confused with the strain insulator used for dead ending a conductor), and three bolt clamps or preformed guy grips. The dimensioning of the guy is determined by the height of the pole, by the amount of strain to be counteracted, and by the climate when the guy is installed. Figure 4-59 shows a typical guy and the method of attaching the come-along for tensioning the guy.

INSTALLING CROSSARMS

As previously discussed in this chapter, crossarms come in various sizes and types, depending on the type of system, size and number of conductors, and voltage of the system.

Figure 4-58.—Tamping and backfilling erected pole.

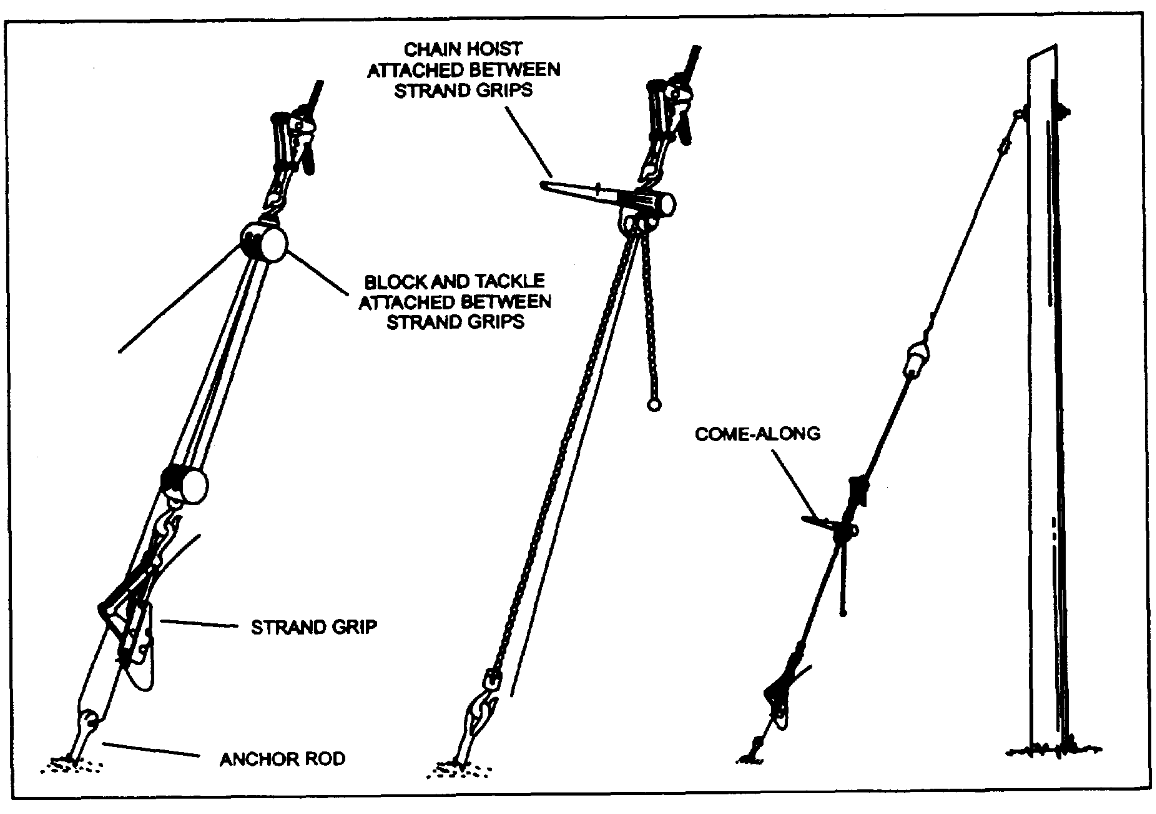
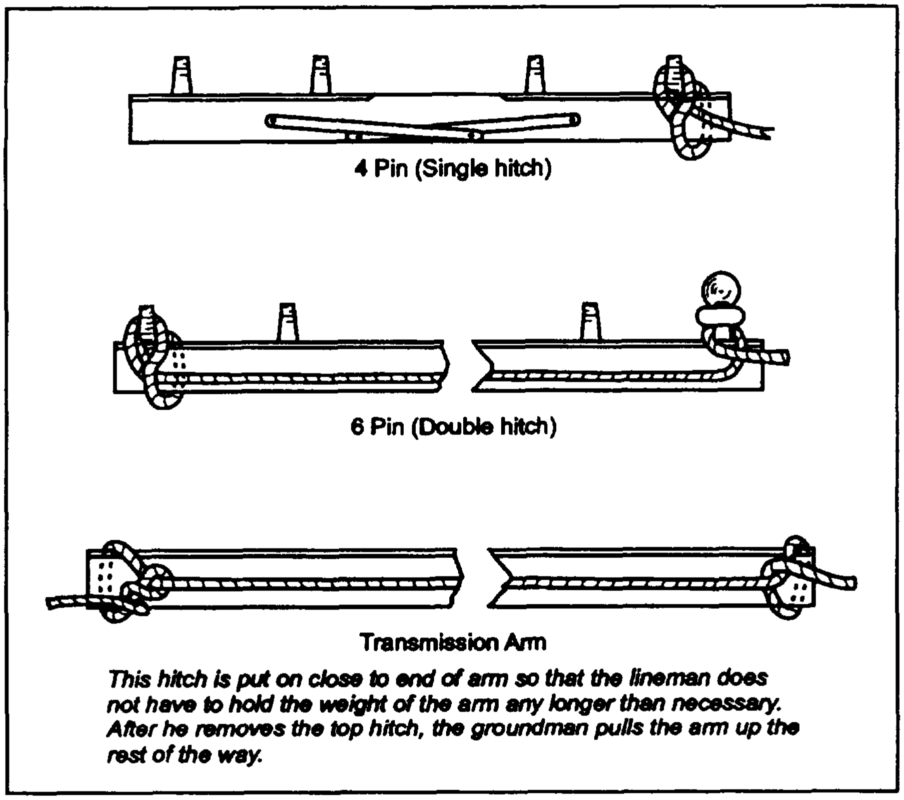


Figure 4-59.—Pulling guys to anchor utility pole.



06NP152

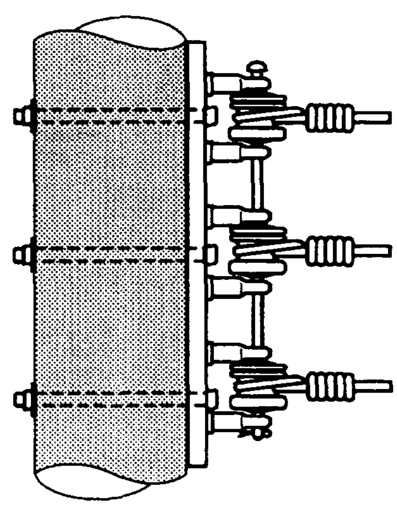
Figure 4-60.—Crossarm, showing proper way to attach a handline.

On most pole-line construction, the installation of hardware and crossarms is accomplished on the ground before setting the pole. This is the easiest and most efficient method; however, sometimes it is necessary to upgrade or build on to an existing system, and then the arm must be installed on a pole that is already standing.

When the crossarm is mounted on the pole before the pole is set, the through bolt is tightened, but the crossarm braces are left hanging loose. Once the pole is set, the crossarm is leveled and the braces are secured to the pole. Finally, the through bolt is drawn completely tight.

When the crossarm is mounted after the pole is set, it is pulled up to a lineman in a working position by a helper on the ground, using a handline attached, as shown in figure 4-60. With the handline attached in this fashion, the lineman can, after he inserts the through bolt, cast off the upper half-hitch, and the helper on the ground can then heave the crossarm level.

Braces are usually fastened to a crossarm with 3/8-inch by 4-inch carriage bolts. Each brace comes down diagonally and is attached to the pole at the lower end with a 1/2-inch lag screw.



06NP152

Figure 4-61.—Dead-end secondary rack.

On a straight line without excessive strains, crossarms are used singly-mounted face-to-face or back-to-back, as previously mentioned. At line terminals, corners, angles, or other points of excessive strain, crossarms are doubled. When a power line crosses a railroad or a telephone line, crossarms should also be doubled.

When double arms are used, they are fastened together at the ends with double-arm bolts. One of these is threaded all the way and has two square washers and two nuts on each bolt between the arms. The lineman can adjust the spacing between a pair of crossarms by setting these nuts the desired distance apart on the threaded bolts.

INSTALLING SECONDARY RACKS

Secondary conductors may be strung on crossarms but are usually put on secondary "racks." These racks are made in sizes to accommodate two, three, or four conductors. A secondary rack is mounted on the side of a pole (for a straight run) or on the inside of a pole (for a dead end). A rack is fastened to the pole with lag bolts on a straight line with a through bolt at the top and a lag screw at the bottom, or with through bolts with nuts for a dead end or when a branch line takes off from the main line. A dead-end secondary rack is shown in figure 4-61.

Insulators are held to a rack by a rod passing through the insulators and brackets on the rack, as shown in figure 4-61. On a straight line or inside angle, the conductor is run on the inside of the insulator. On an outside angle, it is run on the outside. The conductor is always placed here with strain against the insulator. Figure 4-62 shows rack arrangements at comers and angles.

INSTALLING CONDUCTORS

There are various ways of stringing conductors. You may place the wire reels on a truck or on a wire trailer and drive along the right-of-way unreeling the

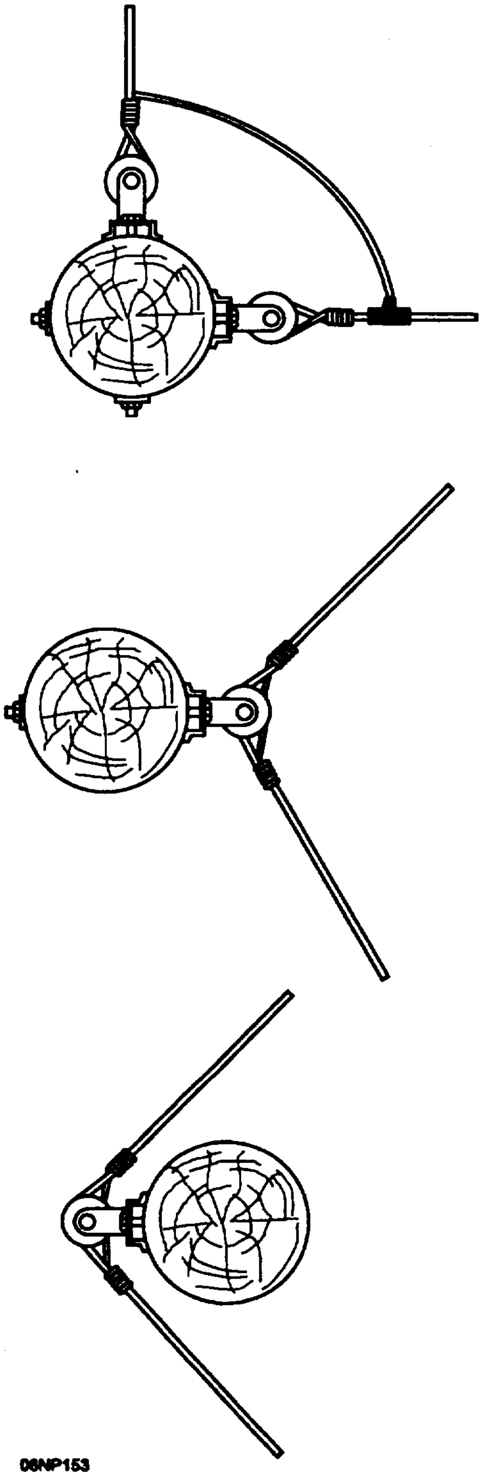
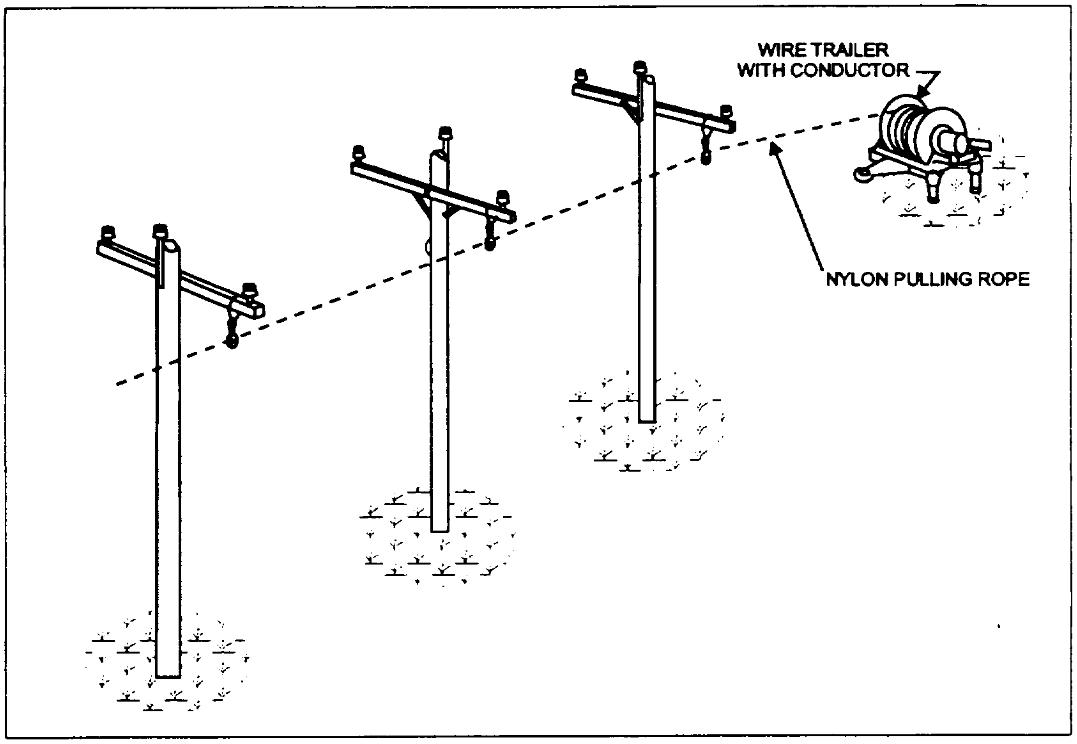


Figure 4-62.—Rack arrangements at corners and angles.



06NP154

Figure 4-63.—Wire trailer with nylon rope used to pull conductor through blocks.

wire, or you may use the running block or over-the-crossarm methods. Figure 4-63 shows the running block method.

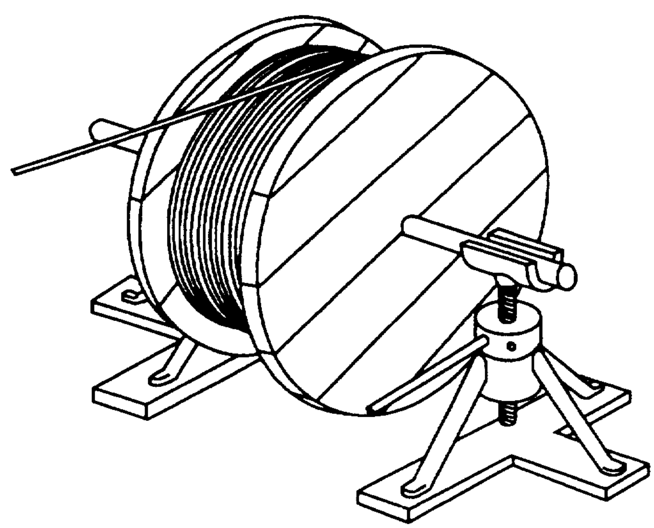
Mounting the Reels

No matter how you string the wire, you will have to mount the reels on some support that allows them to revolve freely. This is usually done by raising a reel on reel jacks, as shown in figure 4-64. A metal rod strong enough to support the reel is put through the hole in the center, and the rod and reel are jacked up on each side with the leg of the T-base away from the reel, as shown. You may have to fasten down the bases of the jacks to keep the strain from upsetting the reel. When you are jacking up, it is necessary only to raise the reel just clear of the deck.

When you are stringing wire in rough terrain, the best method is to anchor a reel to the ground at the end of the line by means of guys run to driven stakes. Then run a rope line over the crossarms or through running blocks mounted on the crossarms for a distance of 1,000 to 1,500 feet. This is accomplished by a lineman climbing each pole and placing the rope in place.

After the rope has been strung over the crossarms, one end is secured to the wires to be pulled, and a couple of turns are taken with the other end around the winch drum on the line truck. The drum is then rotated to haul in the rope and the wires with it. As each wire passes a crossarm, a lineman must climb the pole to set the wire in proper position and guard against twisting.

To keep a paying-out reel from revolving too fast, set a brake or drag against the reel. This can be simply a board, held against the outer edge of the reel by a helper. As a wire or wires are being pulled, enough crew



06NP155

Figure 4-64.—Cable reel on reel jacks.

members must be stationed along the way to establish a chain of signal communication from the head of the line back to the line truck.

Placing the Neutral Conductor

A neutral conductor should always be placed on a center crossarm pin or on a pole-top pin. Butting the neutral on a center pole pin gives the lineman a clear space around the pole to climb through; that is, it ensures that the hot wires are a considerable distance apart.

Pulling In

When the conductors have been hoisted in place on the crossarms and dead-ended on one end, you are ready to start "pulling in"; that is, heaving on the conductors until each has been raised to proper sag. You can do this with a tackle equipped with cable grips like those shown in figure 4-65 or individually, using a cable grip and a come-along.

A cable grip is a clamp device that grips the wire tightly when a strain is applied to the grip.

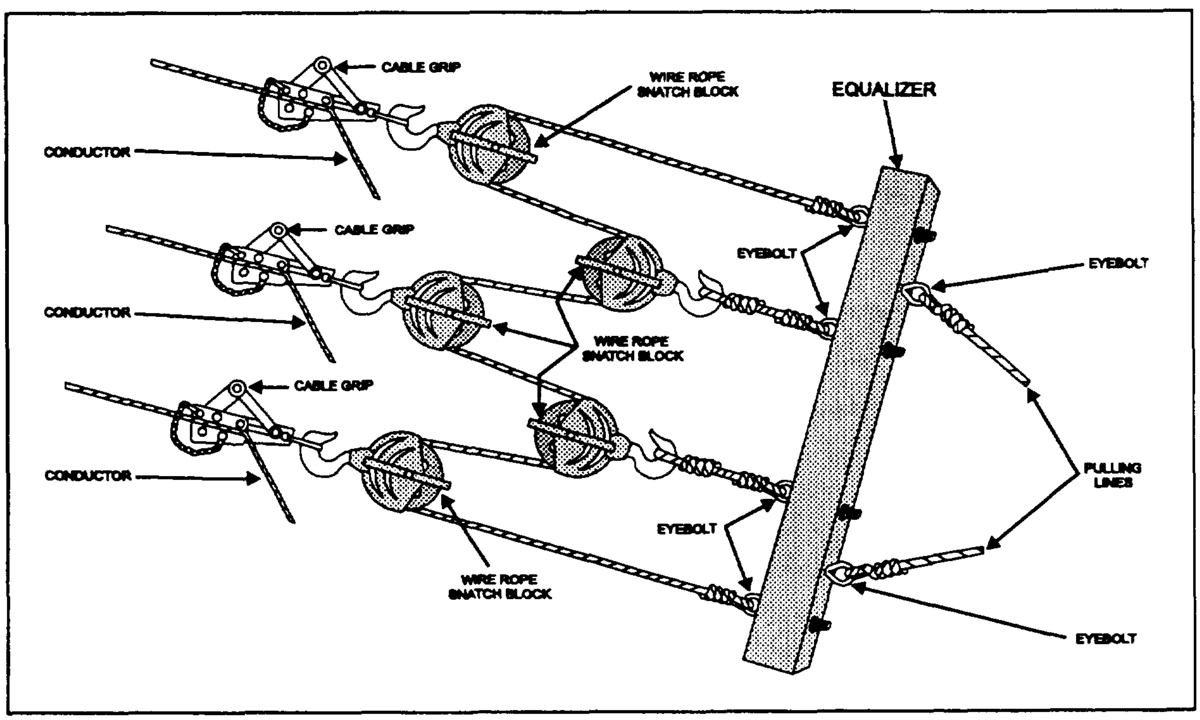
When you are pulling two or more wires at once, it is best to use the equalizer, as shown in figure 4-65. This device distributes the strain equally on all the wires.

Measuring the Sag

When wires have been pulled to approximately the desired sag, a lineman goes to the center span to measure the sag. Measurement at the center of each span ensures uniformity. Three common ways of measuring sag are by dynamometer, by timing vibration, and by the use of targets.

DYNAMOMETER.—Alever-cam dynamometer is an instrument that is installed in the pulling line and that measures the strain of the pull. It is used in conjunction with a chart that gives the desired pull tension for a given conductor size, span length, and temperature. A traction dynamometer, also installed in the pulling line, provides direct readings on the face of the dial.

TIMING VIBRATION.—The timing-vibration process is done by striking the wire sharply near one of the pole supports and by timing with a stopwatch, the interval that elapses as the impulse from the blow travels to the next pole and returns. This system is not accurate when wind is swinging the line or when the line is being worked on in an adjacent span.



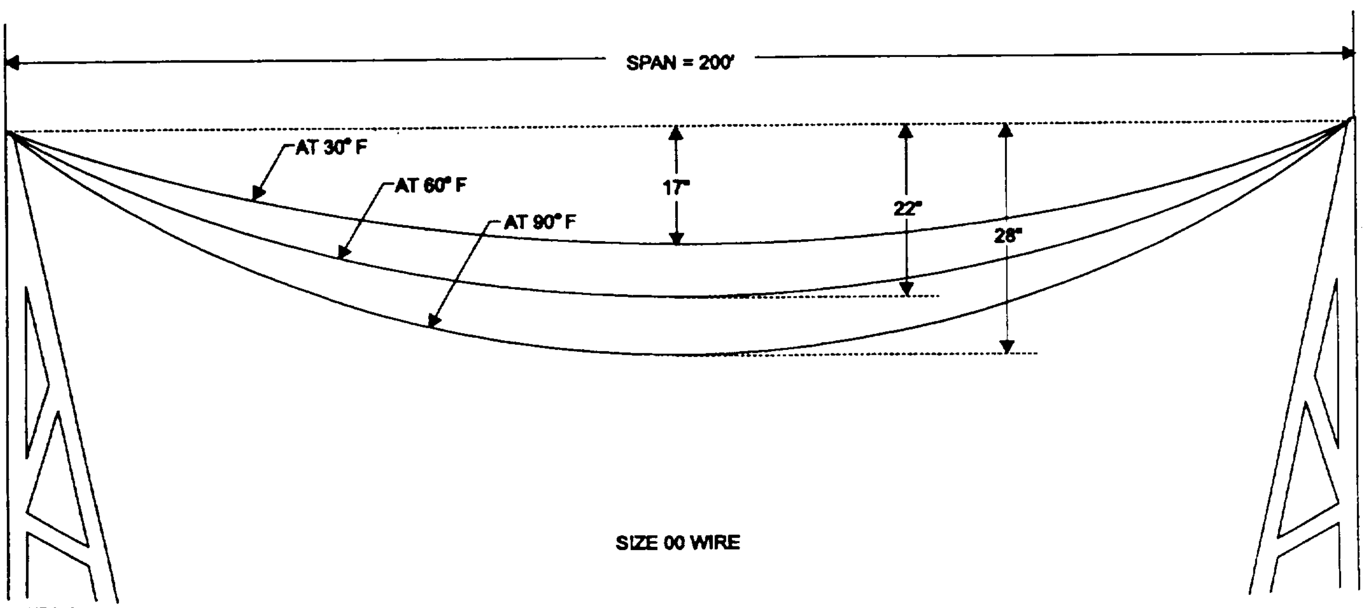
06NP156

Figure 4-65.—Pulling wires with an equalizer.

Table 4-2.—Sag Variation with Temperature

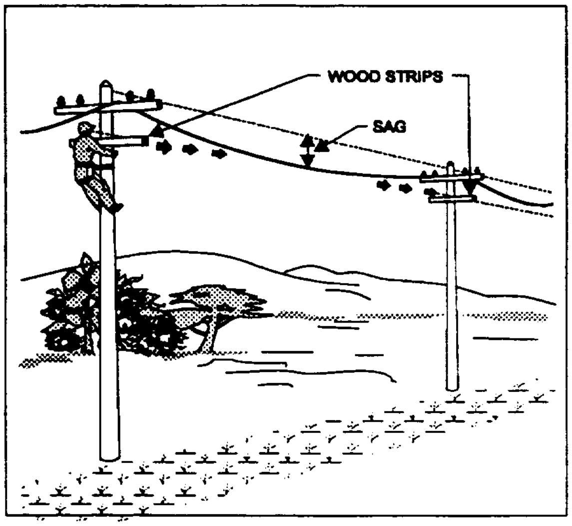
No. (awg)	Temperature (degrees F)	Sag in inches for span lengths of					
		100 ft	125 ft	150 ft	175 ft	200 ft	250 ft
6	30	5.5	8.5	13	18.5		
	60	8	12	18	24		
	90	12	17	23.5	30		
4	30	5.5	8.5	13	18.5	25	35
	60	8	12	18	24	32	42
	90	12	17	23.5	30	39	50
2	30	5.5	8.5	13	16.5	20	29
	60	8	12	18	22	26	36
	90	12	17	23.5	28	33	44
1	30	5.5	8.5	13	15.5	28.5	24.5
	60	8	12	18	21	24	31
	90	12	17	23.5	28	31	39
0	30	5.5	8.5	13	15.5	18	23.5
	60	8	12	18	20.5	23	29
	90	12	17	23.5	27.5	29.5	36
00	30	5.5	8.5	13	15	17	21
	60	8	12	18	20	22	27
	90	12	17	23.5	26	28	34
0000	30	5.5	8.5	13	14.5	16	19
	60	8	12	18	19	21	24
	90	12	17	23.5	25	27	30

06NP157



06NP158

Figure 4-66.—Effect of temperature on sag in 200-foot span of 00 wire.



06NP159

Figure 4-67.—Adjusting sag.

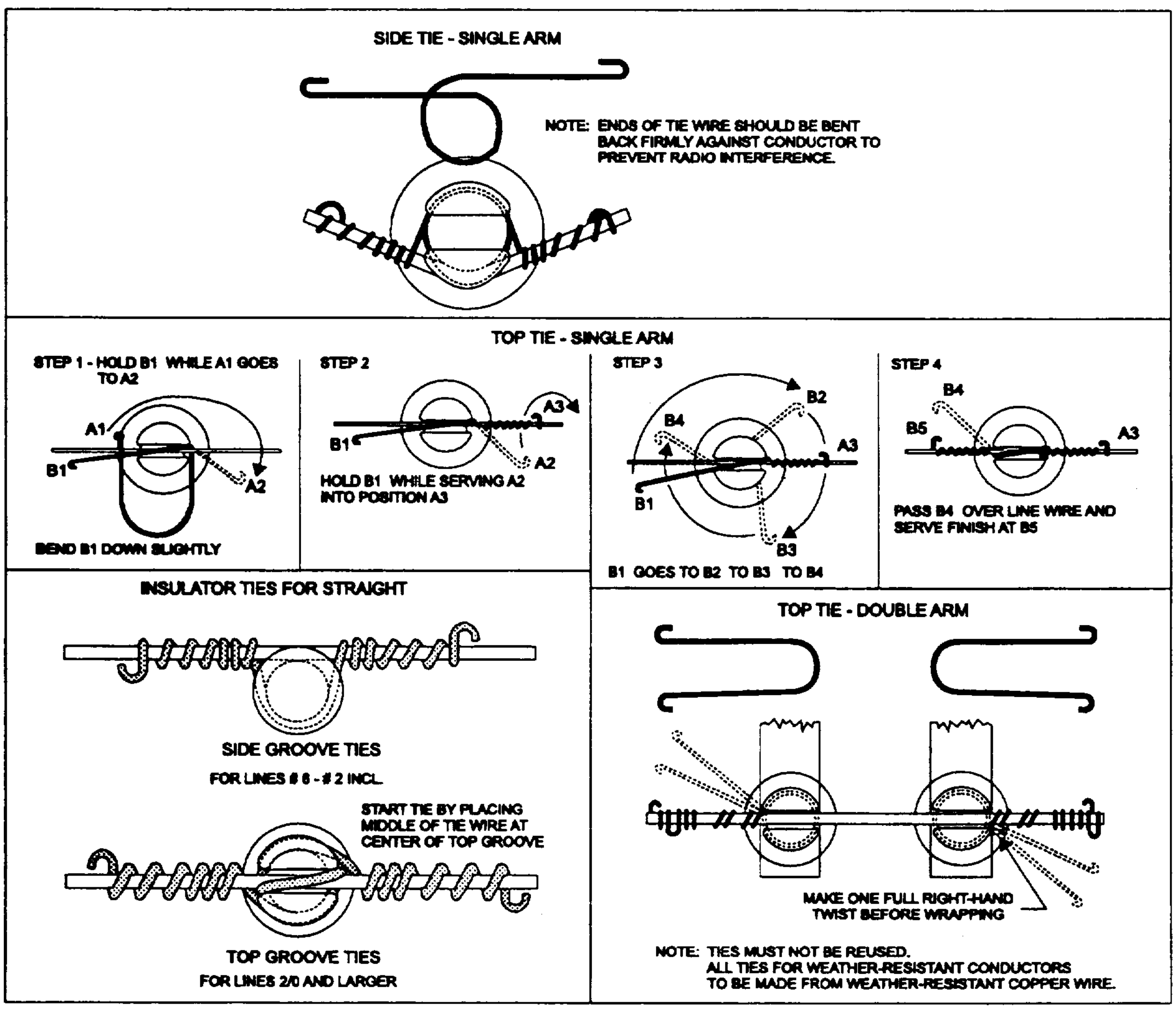
TARGETS.—The target-sighting method is a simple and accurate means for measuring sag. The desired sag is first determined from table 4-2.

Figure 4-66 shows the effect of temperature on the sag in a 200-foot span of 00 wire. You target-measure sag by nailing slat targets, such as a couple of pieces of wood lath, at the point on each pole below the conductor insulator that creates the desired amount of sag. A lineman then sights from one slat to the other, and the conductor is hauled up or lowered until its lowest point is on the line of sight between the slats (fig. 4-67).

After the wires are "sagged in," you allow a rest period of from 1/2 hour to 4 hours (varying according to the length of the pull) to let the wires adjust themselves to the tension in the pull. They will gradually "creep" until tension in all the spans is equalized. After they have crept to the final position, you are ready to "tie in."

TYING IN CONDUCTORS

Tie wire fastens the conductor and insulator together. Conductors can be tied in various ways, but the ties shown in figure 4-68 are the ones most commonly used.



06NP160

Figure 4-68.—Tying in conductors.

A special reminder—When using an aluminum conductor, you are required to cover it with armor rod at each insulator to provide physical protection against rubbing or pitting caused by the elements. Another important requirement is the use of ACSR-rated dead-end shoes, splice connectors, and all other devices that come in direct contact with an aluminum conductor. This is to prevent electrolysis that occurs from the physical contact of dissimilar metals.

In tying in conductors, observe the following procedures:

Always use new, fully annealed wire for ties. Hard-drawn wire is brittle and cannot be pulled up against the conductor and insulator.

Use the proper size wire. For No. 8 bare, use No. 8 bare. For No. 6 or No. 4 bare, use No. 6 bare. Use No. 4 bare for a No. 2 conductor. Use No. 2 bare wire for No. l/O through 4/0 bare conductor.

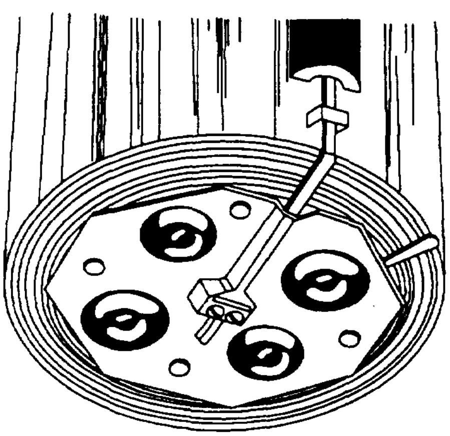
Use a piece of tie wire that is long enough to make the complete tie, with enough left over to allow grasping. After the tie is completed, cut off the excess and form a loop, or eye, at the end of any projecting end of the wire.

Make positive contact between the wire and conductor to avoid chafing and to limit possibilities of causing interference with radio communications. Hold the tie wire tight against the insulator as you make your wraps around the insulator and the conductor wire.

INSTALLING GROUNDS

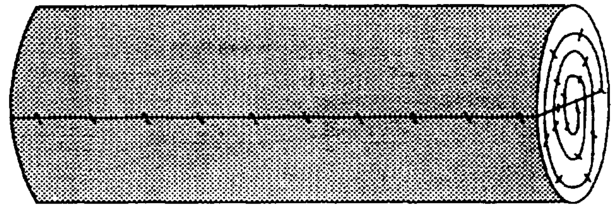
Grounding in the power distribution system is important. The grounding system protects you and the distribution system when faults occur and aids in the suppression of noise. Grounds are required every quarter mile on a power distribution line and at every pole when equipment, such as transformers, regulators, capacitors, switches, circuit breakers, and lightning arresters, is installed. The maximum resistance of any distribution ground is 25 ohms, but a lower resistance is desired.

In new construction a butt ground is placed on the pole before the pole is installed. The butt ground can be a manufactured plate, as shown in figure 4-69, or a coil of bare copper wire, as shown in figure 4-70. On existing distribution lines, a ground rod that is 5/8 inch in diameter and 8 feet long is driven at the base of the pole and tied to the pole with a bare copper grounding conductor and a ground clamp, as shown in figure 4-71.



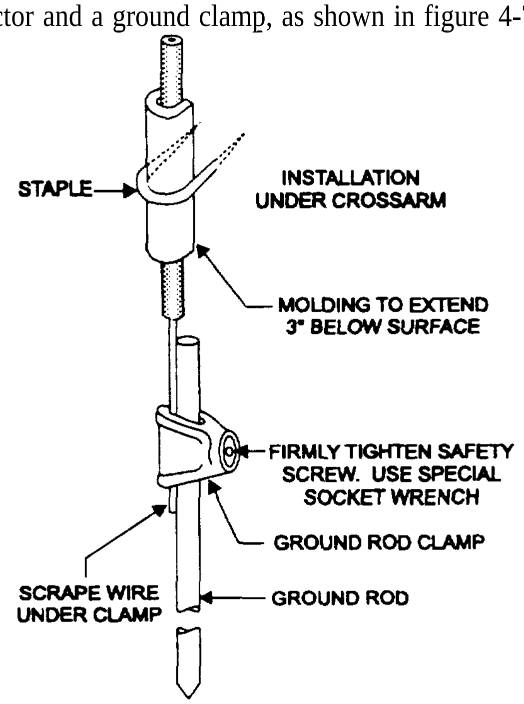
06NP161

Figure 4-69.—Pole with butt ground plate.



06NP162

Figure 4-70.—Pole butt ground, coiled wire type.



06NP163

Figure 4-71.—Pole ground, ground rod type.

The ground wire on the pole is covered by molding from the level of earth to a height of 8 feet.

On the top of the pole, the grounding conductor is connected to the cases of all installed equipment, lightning arresters, and the primary and secondary neutrals of the distribution system, as shown in figure 4-72.

POLE CLIMBING AND RESCUE PROCEDURES

In line work a requirement is to be able to climb poles. The better you become at climbing poles, the easier your work will be. Yet, no matter how good you become at climbing, the potential for a serious accident always exists when you work around high voltage. In this section you will look at the proper methods of maintaining equipment, climbing poles, and performing emergency rescue from the pole and aerial bucket truck.

POLE CLIMBING

A lineman climbing a pole corresponds to an office worker taking an elevator to the top floor of a building to his or her office. Climbing is not the job, but you must learn to climb and be at ease when you get there.

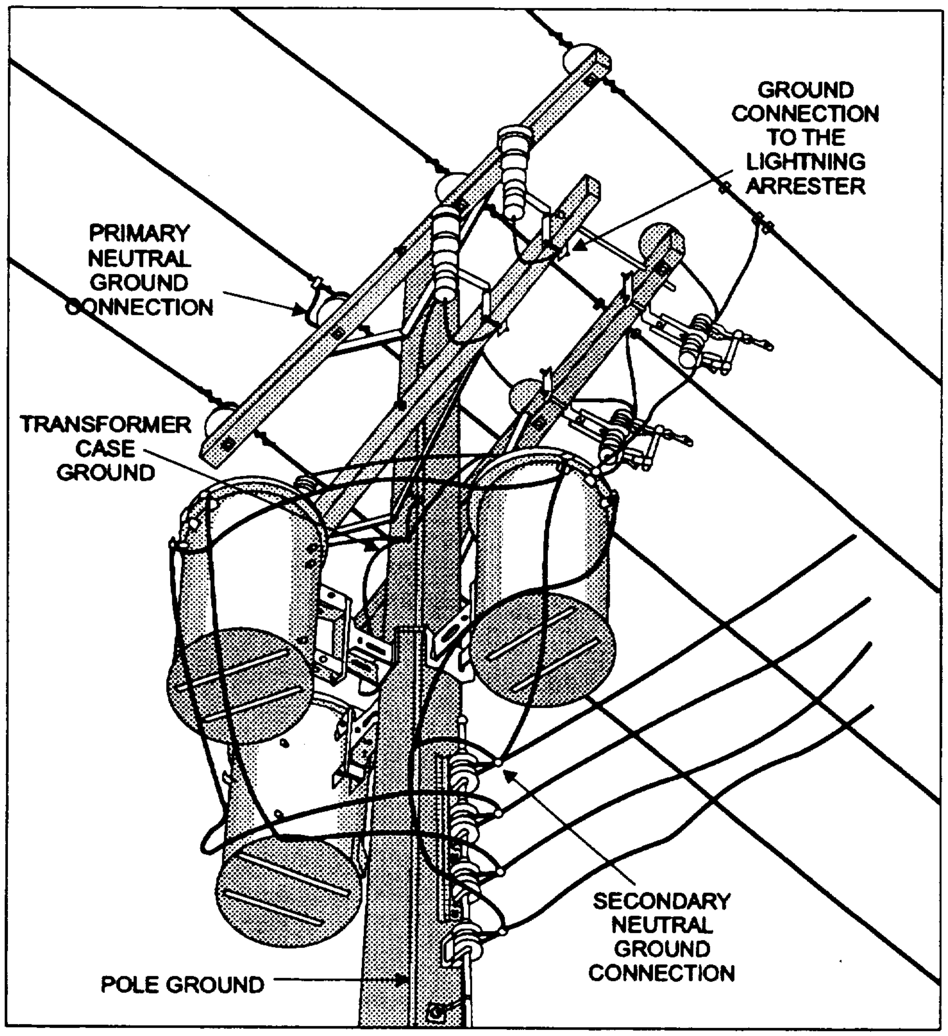


Figure 4-72.—Completely wired installation with wraparound mount showing grounding connections.

To climb a wooden pole or tree, you will use the equipment shown in figure 4-73. On the climber, the stirrup fits under the arch of your foot, and the leg iron runs up the inner side of the calf of your leg. This puts the gaff in a position on the inner side of your foot where you can drive it into the pole or tree as you climb. Two leather straps run through the loop straps and hold the climber tightly against your calf and ankle. The leather pad keeps the upper end of the climber from digging into your leg.

The term *leather* refers not only to treated animal hides but also to neoprene-impregnated nylon products, such as body belts, safety straps, and leg straps. These nonleather items are cleaned with soap and water and are available to the battalions.

The safety strap and body belt, as shown in figure 4-73, are what might be called your extra pair of hands when you work aloft. The safety strap is a leather belt with a tongue type of buckle (keeper snap) at each end. The body belt, strapped around your waist, contains various pockets for small tools. While climbing, you will have the safety strap hanging by both ends from the left ring (called a D ring because of its shape) on the body belt.

The safety strap also has an adjustable buckle that permits varying the length to suit the lineman and circumference of the pole.

Care of Climbing Equipment

To a lineman the term *burning a pole* means the highly unpleasant experience of sliding all the way, or a good part of the way, down a pole as a result of defective equipment or some error in climbing techniques made on the way up. The burning you receive does not need to be explained in detail, and besides burning, you may get many splinters. However, climbers, body belt, and safety strap should keep you up where you belong—if you use them properly and take proper care of them.

The body belt and safety strap require continuous inspection. Look for the following:

- Loose or broken rivets
- Cracks, cuts, nicks, or tears in leather
- Broken or otherwise defective buckles
- Defects in safety-belt snap hooks and body-belt D rings

Figure 4-73.—Pole climbing equipment.

- Worn leather

- Enlarged tongue holes for belt buckles

If you discover any of these defects, turn in the equipment and replace it.

You must periodically perform maintenance work on the leather parts of your climbing equipment. Cleaning comes first. Use a damp sponge and a mild soap. Work up a thick, creamy lather. Then wash the soap off and wipe the belt with a dry cloth.

Next, to make the genuine leather soft and pliable, lather well with saddle soap. Work the lather into all parts; then place the belt in the shade to dry. After the lather has nearly dried, rub down the leather with a soft cloth.

Both belts and safety straps, made of genuine leather, require oiling about every 6 months. Be sure the leather is clean before applying oil. Use about 2 teaspoonfuls of neat's-foot oil, working the oil in gradually. Place the belt in a shady place and allow it to dry for 24 hours. Then rub it down with a soft cloth.

Always, before you climb a pole or tree, inspect the climbers for the following defects:

- Broken or loose straps

- Stirrup worn to a thickness of one-eighth inch or less

- Length of pole gaff of less than one-fourth inch as measured along the inner surface

- Length of tree gaff of less than 5 1/2 inches as measured along the outer surface and of less than 3 1/2 inches along the inner surface

- Difference in gaff lengths of more than one-eighth inch

If you find any of these defects, turn in your climbers for a new pair.

Climber's Gauge

To minimize certain dangers that can occur from neglect of the climbers, make sure you check your gaffs frequently, using a climber's gauge (fig. 4-74). This gauge is used to check the dimensions of the gaffs. These must be within certain tolerances or the climber will "cut out" or lose contact with a pole or tree.

Measurements of the length, width, and thickness of the gaffs are made as follows (fig. 4-75):

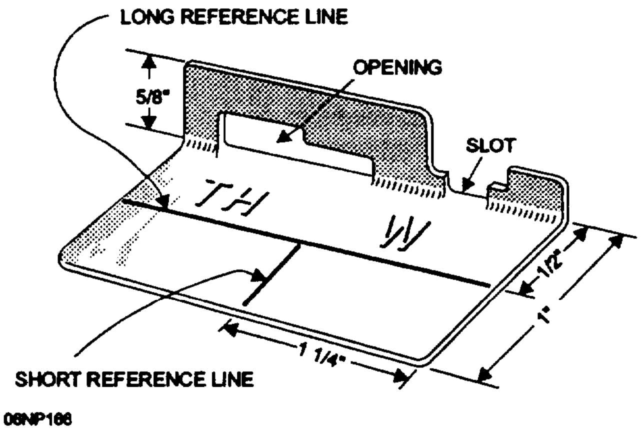


Figure 4-74.—Climber's gauge.

LENGTH. Place the lined face of the gauge against the inner surface of the gaff, with the short edge of the gauge held tightly against the crotch (fig. 4-75, view A). The crotch is the point where the gaff joins the leg iron of the climber. If the point of the gaff extends to or beyond the short reference line, the length of the gaff is satisfactory.

WIDTH. Insert the gaff as far as possible through the small slot marked "W," with the inner surface of the gaff resting against the lined face of the gauge (fig. 4-75, view B). If the point of the gaff does not extend beyond the long reference line, the width of this section of the gaff is satisfactory. Insert the gaff as far as possible

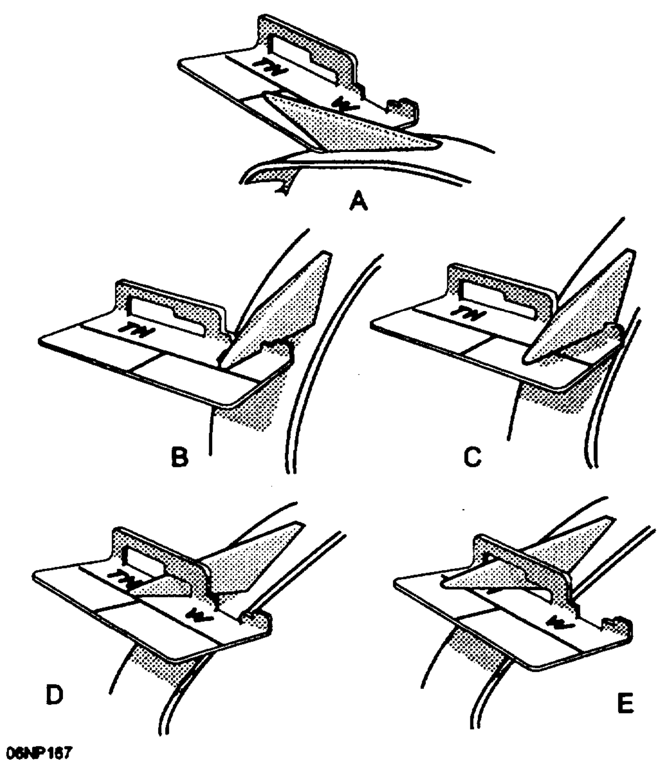


Figure 4-75.—Use of climber's gauge.

through the large slot marked "W," with the inner surface of the gaff toward the lined face of the gauge (fig. 4-75, view C). If the point of the gaff does not extend beyond the far edge of the gauge, the width of this section of the gaff is satisfactory.

THICKNESS. Insert the gaff as far as possible through the small opening marked "TH," with the inner surface of the gaff resting against the lined face of the gauge (fig. 4-75, view D). If the point of the gaff does not extend beyond the reference line, the thickness of this section of the gaff is satisfactory. Insert the gaff as far as possible through the large opening marked "TH," with the inner surface of the gaff resting against the lined face of the gauge (fig. 4-75, view E). If the point of the gaff does not extend beyond the far edge of the gauge, the thickness of this section of the gaff is satisfactory.

Sharpen dull gaffs by taking long strokes with a file from the heel to the point of the gaff, removing only enough material to make a good point. NEVER USE A GRINDSTONE OR EMERY WHEEL TO SHARPEN GAFFS, since the metal may become overheated and lose its strength (temper). Never sharpen the gaff to a needlepoint (fig. 4-76) since it would sink too deeply into the pole and make climbing difficult. Always leave a shoulder about one-eighth inch back from the point.

Remember that climbers are for use on poles ONLY. Do not wear them while working on the ground, and do not use the gaffs for such irregular procedures as the opening of cans.

Going Up

Before you start to climb a pole, there are a number of preliminary steps that you should take. First, of course, make the preclimb inspection of equipment previously described AND PUT ON YOUR HARD HAT. Then inspect the pole to determine the best side on which to start. This is usually the back, or high side.

Get against the pole and grasp each side of it with your hands—not that you will hand support your weight in climbing, but simply because you will use your hands to help in balancing yourself on the climbers (fig. 4-77).

To learn pole climbing, you must practice actual pole climbing. Some pointers that will help you become proficient in pole climbing in minimum time are as follows:

Raise your right leg about 8 inches off the ground and sink the gaff on that leg into the pole. Do not jab the gaff in the wood. Allow your weight to sink it in. Now, swing yourself up off the ground and lock your right leg in a stiff-legged position so that all your weight is supported on that leg.

At the next step, raise your left foot about 8 inches and sink the gaff on that foot into the wood. Then swing up onto the left leg, stiff-legged, and take the next step similarly with the right foot. Continue this stepping up and locking stiff-legged until you reach working position. Keep the upper-part of your body away from the pole (fig. 4-78); if you were to "hug" the pole, you would tend to throw the gaffs out of the wood.

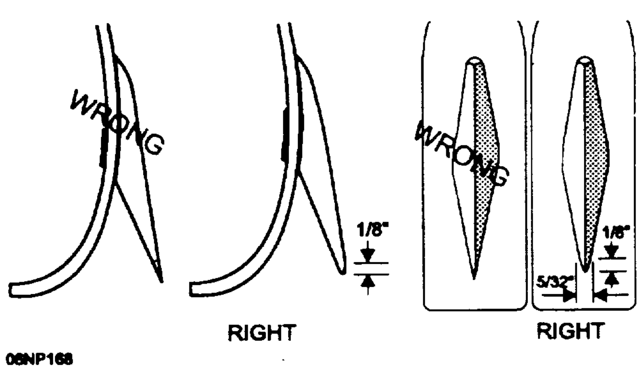


Figure 4-76.—Sharpening the gaffs.

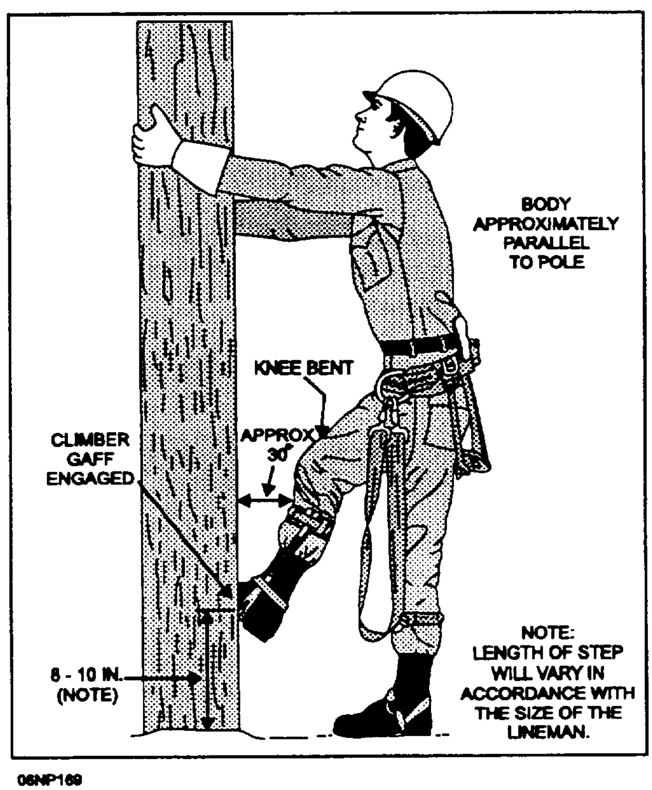


Figure 4-77.—Starting to climb a pole.

Figure 4-78.—Continuing the climb.

When you reach the working position, proceed immediately with great care to attach the safety strap. You should place your feet so that most of the weight is on the right foot, with the right knee locked. The left foot should be slightly above the right foot and the left leg should be slightly bent.

Crook your right arm around the pole. Use your left hand to unsnap one end of the safety strap from the left D-ring on the body belt. Holding the end of the safety strap in your left hand, pass it around the back of the pole. Transfer the end of the safety strap from the left hand to the right hand; at the same time, crook your left arm around the pole to hold yourself in position. Then swing the end of the safety strap quickly around with your right hand and snap it onto the right D-ring on the body belt.

WARNING

Visually check to ensure that the snap hook on the safety strap is hooked on the D-ring and that the keepers on the snap hooks on both ends of the strap are facing away from your body. When you are sure the strap is secure, you may slowly lean back against the safety strap, as shown in figure 4-79.

Coming Down

Before starting down the pole, you must release the body belt. Crook your left arm around the pole, and unhook the safety strap from the right D-ring with the right hand. Pass the end of the safety strap to the left hand, crook your right arm around the pole, and snap the end of the safety strap to the left D-ring.

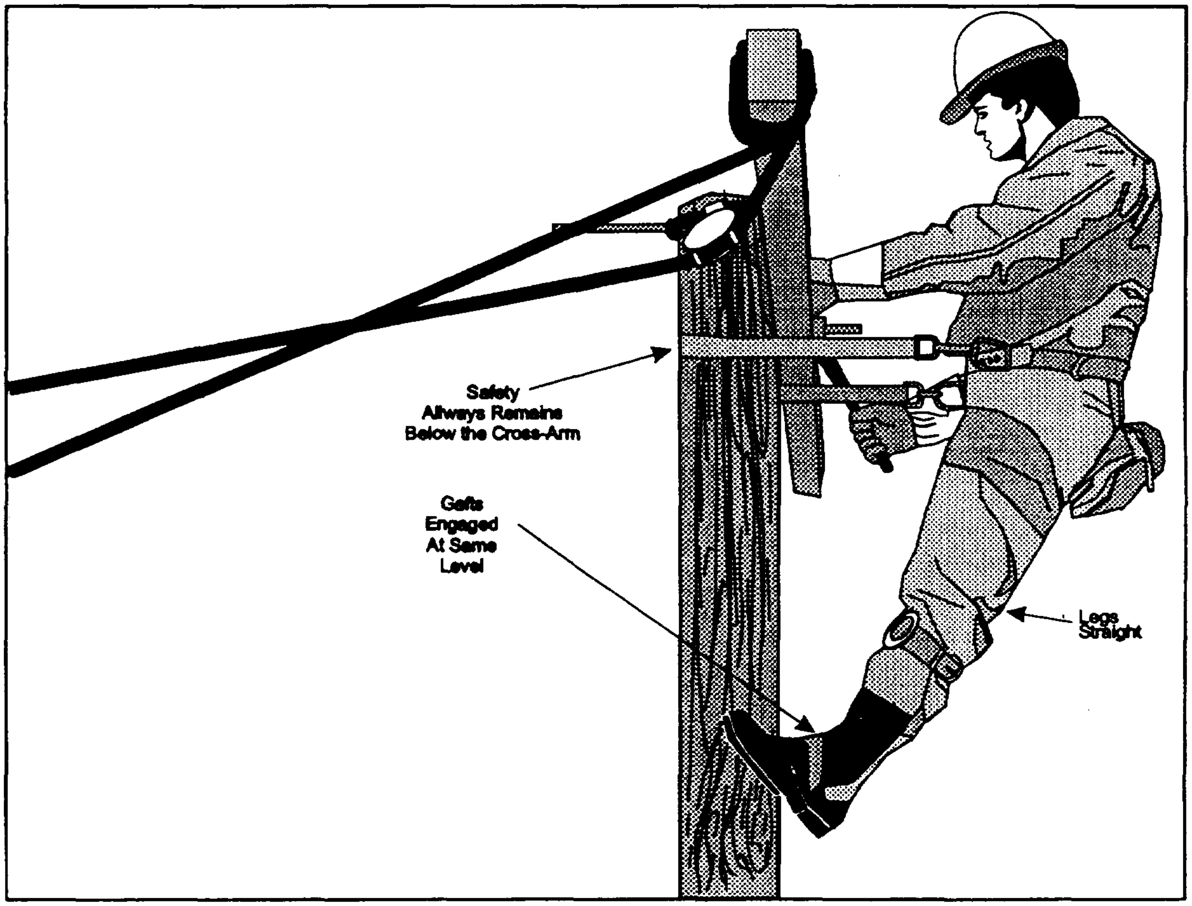


Figure 4-79.—Working position.

You are now ready to descend. Break out the left gaff by swinging the left knee out from the side of the pole. Step down with the left foot to a point about 12 inches below the right; stiff-leg the left leg, and bring your weight on it to sink the gaff. Then break out the right gaff by swinging the right knee away from the pole (fig. 4-80) and proceed as formerly with the left leg. Continue this stepping-down process until you have reached the ground.

Safety in Pole Climbing

Never climb an erected pole until it has been plumbed, backfilled, and tamped. Before going aloft on an old pole, perform a butt rot test on the pole to assure yourself that the pole is strong enough to withstand your weight, and then carefully perform the previously described inspection of the body belt, safety strap, climbers, and other equipment.

The body belt contains pockets for small tools. Keeping the tools in these pockets is important. Never use the center loop in the body belt for carrying a tool, however. In case of a fall, the tool may injure your tailbone.

If you try to climb with tools in your hands, your own balance on the pole will be unsafe, and you could drop tools on someone below.

The safety strap is used to secure you to the pole, leaving your hands free to work. As you go up, the safety strap is always fastened to a single D-ring on the body belt. For a right-handed person, it is carried on the left D-ring.

Never use an improvised safety strap, or one that has been lengthened by the addition of rope or wire. Never attach the strap to pins or to crossarm braces. Never put the safety strap around the pole above the highest crossarm if the length of the pole above the crossarm is short. The strap should never be less than 1 foot below the top of the pole.

Never wear climbers except for climbing. Be careful not to gaff yourself or anybody else.

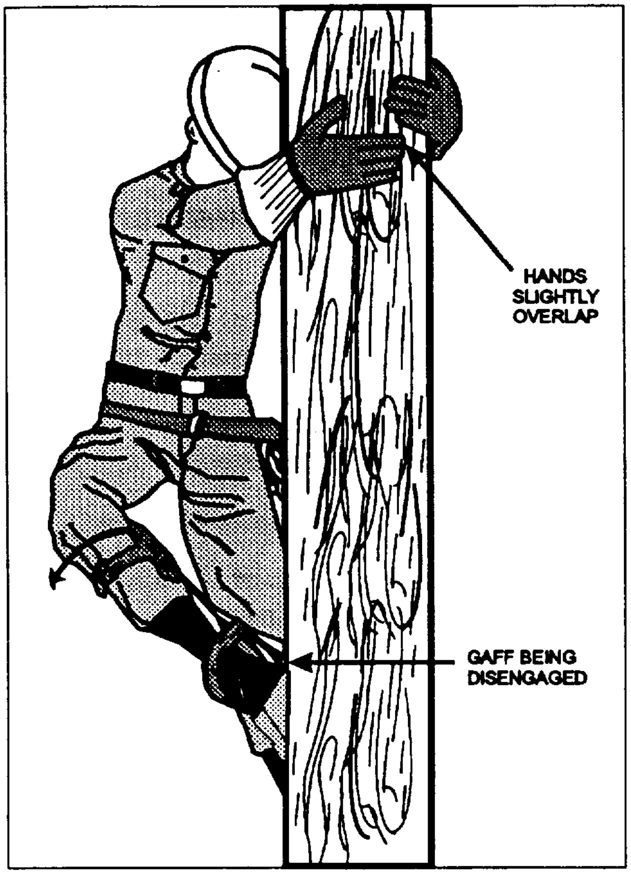


Figure 4-80.—Descending.

Some precautions to keep constantly in mind are as follows:

- NEVER carry tools or other objects in your hand when climbing.
- NEVER trust pins,crossarmbraces,orguywires as supports.
- If you are working with another person on the same pole and he or she goes up first, wait until he or she is strapped in the working position before you start up.
- Do not depend on the snapping sound when you snap the safety strap to a D-ring. Look down to ensure that the snap is hooked on the ring.
- If the top crossarm is near the top of the pole, do not pass the strap around the short length of the pole protruding above the crossarm.
- Ensure that keepers on the snap hooks on the safety strap are facing away from the body.

Protective Clothing and Equipment

A lineman should always wear gloves or gauntlets when tending a reel for stringing conductors. Never work with the gauntlets of the gloves turned down

Do not wear hobnailed shoes or shoes with metal plates. When trimming trees for pole lines, wear rubbers or rubber-soled shoes for climbing. Always test the safety strap and body belt before using them. Never wear a strap with stitching across it or one mended with tape. Make all the safety checks of climbing equipment every time you prepare to go aloft.

POLE-TOP RESCUE

When a crew member working aloft is shocked into unconsciousness, there are several ways of performing pole-top resuscitation, depending on the prevailing circumstances.

There are some basic steps that you must take when accomplishing a pole-top rescue. First, you need to <u>evaluate</u> the situation; second, you should <u>provide</u> for YOUR safety; third, you have to <u>climb</u> to position where you can attempt the rescue; and fourth, you need to <u>determine</u> the seriousness of the victim's condition and <u>take</u> the necessary action to accomplish the rescue.

EVALUATE THE SITUATION. Call out to the victim, "Hey! Do You Need Any Help", "Are You O.K.?" If there is no response or if the victim seems stunned or dazed, prepare to do a rescue. At this point, TIME IS EXTREMELY IMPORTANT! While calling to the victim, look at the surroundings. Look for things such as the pole or crossarm being split, cracked or on fire. If the victim is in contact with an energized conductor you will need to clear him or her using rubber goods or hot stick. When evaluating the scene look at the whole scene and not just the victim.

WARNING

To ensure your personal safety, you need to wear rubber gloves or sleeves and take enough other equipment to secure your position

PROVIDE FOR PERSONAL PROTECTION. Consider turning off the electricity, but don't waste time looking for a switch, the rescue is more important. Your safety is very important to the rescue mission Without you, there will be no rescue. This means personal climbing equipment and rubber goods are in serviceable condition. Hot line tools are ready in case needed and physical condition of the pole has been surveyed. Plan your route to the victim now. To be on the safe side assume the pole is energized; unless confirmed de-energized. Leap onto the pole. No part of your body should touch the pole and the earth at the same time. This prevents your body from providing an alternate path for the electricity. Remember, don't take chances and become a victim also.

CLIMB TO RESCUE POSITION. Lay out the rescue rope and attach one end to a loop of your body belt. While climbing to the rescue position, be sure to climb carefully and belt in at a safe position. Clear the victim from energized conductors using rubber goods or hot sticks, then reposition yourself and determine the victim's condition. Slightly above and to one side is normally best for checking and working with the victim.

A safe and easy method used to lower the victim to the ground is shown in figure 4-81 and requires a pulley line or a handline attached to a crossarm and tied off around the victim's chest. The knot should be in front of the victim, close to one armpit. lie three half-hitches, and snug the knot so that the rope rides high on the victim's chest Take up the slack, cut the victim's safety strap, and slowly lower him or her to the ground.

MAINTENANCE OF POWER DISTRIBUTION SYSTEMS

The elements, accidents, and willful vandalism are the causes of most damage to power distribution

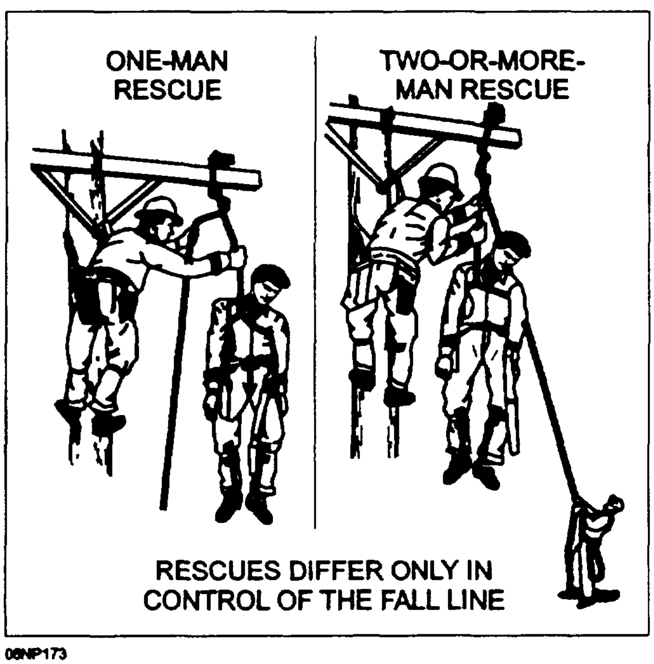


Figure 4-81.—Pole-top rescue.

equipment. To repair these damages, the lineman requires experience, a total commitment to safety, and the knowledge to accomplish repairs to the system as quickly and economically as possible.

MAINTENANCE OF POLES, TIMBERS, AND CROSSARMS

The maintenance required on the poles, timbers, and crossarms in a power distribution system is minimal. Normally, this equipment lasts for a period of 20 years or more. The following problems may occur, however, and create a need for maintenance action:

- A pole can settle and require straightening.
- Wood can shrink and cause all hardware to become loose and require tightening.

WOOD POLE MAINTENANCE

Wood poles are treated with preservatives to prevent decay, but small organisms, insects, and fungi all contribute to the breakdown of the wood preservatives. The life of a pole can be extended by inspections and treatment, when necessary, to stop pole decay.

The inspection would normally include sounding the pole by hitting it with a hammer from belowground level to approximately 6 feet above ground to determine obvious defects. Also the pole is bored to determine the presence of internal voids. Poles with internal decay can be treated with insecticides. External decay is removed, and the area is treated with preservatives and wrapped with a moisture-proof barrier. Poles weakened excessively by internal or external decay must be reinforced or replaced.

MAINTENANCE OF HARDWARE, CONDUCTORS, ACCESSORIES, AND GUYS

Other items that may require maintenance are the hardware, conductors, accessories, and guys.

- Over time, guys stretch and require re-tensioning.
- Insulators get dirty and require cleaning, especially around the sea where there is salt in the air.
- Connections become loose with age and must be re-torqued to prevent hot spots.

- In time, conductors stretch and require re-sagging.
- Insulators crack and require replacement.

OPERATOR MAINTENANCE RESPONSIBILITY

Operators must keep the vehicle or assigned equipment clean and in serviceable condition and must perform daily operator's maintenance. Equipment must be inspected daily and any defects noted to be corrected before a serious breakdown or mishap occurs. The NCF equipment is scheduled for preventive maintenance every 40 workdays. No piece of equipment can be expected to operate for 40 days without daily operator care. Many units of equipment have hourly and daily lubrication points. This lubrication is the responsibility of the operator. Operators must ensure that equipment is maintained as outlined in the operator's manuals. These manuals can be obtained from the CM shop library.

MAINTENANCE AND TESTING OF AERIAL EQUIPMENT WITH HYDRAULIC BOOM

Operation of aerial equipment starts in the same way as other pieces of equipment. The operator must have a valid license, and a thorough prestart inspection must be performed. Maintenance and lubrication must be performed according to the manufacturers' recommendations and guidelines. Daily operator checks, made before placing the equipment in service and again when securing the equipment, will be kept on file for a minimum of 60 days. If the operator detects any condition that would indicate the equipment to be unsafe or unreliable for use, the equipment must be removed from service.

A **condition inspection,** an **electrical insulation test,** and a **load test** are to be performed annually. The certifying official of the designated activity is responsible for the certification of these inspections and tests. A copy of the certification must be posted on the equipment in full view of the operator. The original certification form is to be filed in the equipment history record file.